

Phase II Ground Safety Data Package for the Alpha Magnetic Spectrometer-02 (AMS-02) and Ground Support Equipment

Systems Architecture and Integration Office
Engineering Directorate

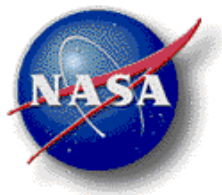
Verify this is the correct version before use

For correct version go to: <http://ams-02project.jsc.nasa.gov/html/GSDP.htm>

Revision A

Phase I/II

October 21, 2008



National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center

EXPORT CONTROL STATEMENT:

The AMS-02 payload has been reviewed by the Department of State and has been declared public domain data under ITAR (see ODT Case CJ 015-01). The payload has also been reviewed by the Department of Commerce and has been categorized 1A999 (see CCATS# G026926), which allows free distribution of data to foreign nationals of all

NASA - LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

Phase I/II

**Ground Safety Data Package
For the
Alpha Magnetic Spectrometer-02 and Ground Support Equipment**

Prepared By:

E. Harvey, SSE, ESCG

Approved by:

J. Rainwater, SSR&M Section Manager, ESCG

C. Tutt, Project Manager, ESCG

T. Martin, Project Manager/NASA

DESCRIPTION OF CHANGES TO

AMS and Ground Support Equipment Ground Safety Data Package

CHANGE LTR.	Originator/Phone Number	DATE	PAGES AFFECTED
Basic	Eric K. Harvey/281-461-5509	May 2008	All
A	Eric K. Harvey/281-461-5509	October 2008	<p>The following changes made per comments from the KSC Phase II ground safety review: 4, 9, 15, 20, 44, 48, 52, 60, 67, 72, 75, 77, 78, 82, 83, 88, 91, 94, 95, 96, 97</p> <p>The following changes made per comments received from the CCB review after the phase II ground safety review: xvii, 12, 20, 22, 24, 32, 33, 39, 40, 42, 48, 52, 53, 60, 56, 87, 97</p>

TABLE OF CONTENTS

1.	PURPOSE	1
2	SCOPE.....	1
3	MISSION SCENARIO	1
4	PAYLOAD OVERVIEW	1
4.1	CRYOGENIC SUPERCONDUCTING MAGNET (CRYOMAGNET)	2
4.1.1	Magnetic Coils	2
4.1.2	Structural Support	4
4.1.3	Cryogenic System	5
4.1.3.1	Coil Cooling	8
4.1.3.2	Helium Tank.....	8
4.1.3.3	Vapor Cooled Shields (VCS)	9
4.1.3.4	Cryocoolers	10
4.2	VACUUM CASE.....	11
4.3	UNIQUE SUPPORT STRUCTURE-02 (USS-02)	11
4.4	TRANSITION RADIATION DETECTOR (TRD) AND ASSOCIATED GAS SYSTEM	12
4.4.1	TRD Structure	12
4.4.2	TRD Gas Supply System.....	15
4.4.2.1	Box S Description	19
4.4.2.2	Box C Description.....	20
4.4.2.3	Straw Tube Segments.....	22
4.4.2.4	Monitoring and Control.....	22
4.5	TIME OF FLIGHT (TOF) SCINTILLATOR COUNTERS.....	25
4.6	STAR TRACKER	27
4.7	ANTI-COINCIDENCE COUNTERS (ACC)	27
4.8	SILICON TRACKER.....	28
4.9	RING IMAGING CERNEKOV COUNTER (RICH).....	29
4.10	ELECTROMAGNETIC CALORIMETER (ECAL).....	30
4.11	POWER DISTRIBUTION SYSTEM (PDS)	32
4.12	HIGH VOLTAGE SOURCES.....	34
4.13	THERMAL CONTROL SYSTEM (TCS).....	35

4.14	MICROMETEOROID AND ORBITAL DEBRIS (MMOD) SHIELDING	35
4.15	GLOBAL POSITIONING SYSTEM (GPS)	36
5	GROUND SUPPORT EQUIPMENT (GSE) SUBSYSTEMS.....	36
5.1	CRYOGENIC GROUND SUPPORT EQUIPMENT (CGSE).....	36
5.1.1	300-80 K System	41
5.1.1.1	Cryostat	41
5.1.1.2	Compressor System.....	41
5.1.1.3	Heat Exchanger HX2	42
5.1.1.4	Warm Helium Gas Supply	42
5.1.2	LHe Transfer Dewar/ LHe Master Dewar.....	44
5.1.3	Liquid (L) and Gas (G) Valve Boxes	46
5.1.4	Vacuum Pump System	51
5.1.4.1	On-Board Pump.....	52
5.1.5	Turbomolecular Vacuum Pump	52
5.1.6	Gaseous Helium (GHe) for Superfluid Cooling Loop (SFCL)	52
5.1.7	Pilot Valve Vacuum Vessel (PVVV) Pump.....	54
5.1.8	VH1 Heat Exchanger	54
5.1.9	Flight Helium Tank Fill Bayonet and Lines.....	55
5.1.10	Pneumatic system.....	58
5.1.11	Support Stands for CGSE Cryogenic and Vent Lines.....	58
5.1.12	CGSE Electrical System.....	59
5.1.13	The Helium Leak Detector	61
5.2	TRD GSE	61
5.2.1	Passive TRD Pressure Stabilization System	62
5.2.2	Xenon and Carbon Dioxide Supply Filling System	63
5.3	WARM HELIUM GAS SYSTEM GSE	64
5.4	TCS GSE	65
5.5	AMS-02 GPS GROUND SYSTEM TEST EQUIPMENT.....	65
5.6	STAR TRACKER GSE.....	67
5.7	GROUND HANDLING EQUIPMENT (GHE).....	67
5.7.1	Primary Support Stand (PSS).....	67
5.7.2	Lower USS (LUSS) Shipping Assembly	78
5.7.3	Primary Lifting Fixture (PLF).....	78

5.7.4	Multi-Purpose Lifting Fixture (MPLF)	79
5.7.5	Intermediate Support Fixtures (ISFs)	80
5.8	ELECTRICAL GSE (EGSE)	81
5.9	KSC SUPPLIED GSE.....	83
6	OPERATIONS SUMMARY	83
6.1	PRE-PAYLOAD ARRIVALS	83
6.2	PAYLOAD ARRIVAL	83
6.3	SSPF ACTIVITIES	84
6.4	CRF ACTIVITIES	84
6.5	PCR ACTIVITIES	84
6.6	ORBITER/PAD ACTIVITIES	84
6.7	CONTINGENCY OPERATIONS	85
7	SAFETY DISCUSSION.....	85
7.1	FIRE	85
7.2	TOXICITY	86
7.3	LIQUEFACTION OF ATMOSPHERIC GASES	86
7.4	PRESSURE SYSTEMS	87
7.5	HIGH PRESSURE GAS.....	88
7.6	TOUCH TEMPERATURES.....	88
7.7	LOSS OF BREATHABLE ATMOSPHERE	89
7.8	IONIZING RADIATION	91
7.9	RF RADIATION	92
7.10	STRUCTURES.....	92
7.11	ELECTRICAL SYSTEMS	93
7.12	ACOUSTICS	93
7.13	MAGNETIC FIELDS	93
7.14	SHARP EDGES	94
7.15	LASERS.....	94
7.16	BIOMEDICAL SUBSYSTEMS.....	94
7.17	ORDNANCE.....	94
7.18	MECHANICAL AND/OR ELECTROMECHANICAL DEVICES	95
7.19	PROPELLANTS.....	95

7.20	OXYGEN	95
7.21	BATTERIES	95
7.22	SAFETY RELATED FAILURES AND MISHAPS	95

LIST OF FIGURES

Figure 4-1 AMS-02 Flight Hardware (MLI not shown).....	2
Figure 4.1.1-1 Magnetic Coils	3
Figure 4.1.1-2 External Magnetic Field.....	4
Figure 4.1.2-1 Magnet Support Strap	5
Figure 4.1.3-1 AMS-02 Cryogenic Schematic	7
Figure 4.1.3.1-1 Heat Exchanger	8
Figure 4.1.3.2-1 Helium Tank (Outer Cylinder Not Shown).....	9
Figure 4.1.3.3-1 Vapor Cooled Shield Structural Support.....	10
Figure 4.2-1 Vacuum Case	11
Figure 4.3-1 USS-02 Attached to Vacuum Case	12
Figure 4.4.1-1 TRD Structure	13
Figure 4.4.1-2 Composition of Straw Wall.....	14
Figure 4.4.2-2 TRD Gas Supply System	17
Figure 4.4.2-3 TRD Gas Supply System (Box S) as Mounted on USS Structure(With Outer Debris Shield Removed).....	18
Figure 4.4.2.1-1 Box S Schematic	20
Figure 4.4.2.2-1 Box C Schematic.....	21
Figure 4.4.2.3-1 One of the 10 TRD Straw Tube Segments.....	22
Figure 4.4.2.4-1 High Voltage System	24

Figure 4.4.2.4-2 High Voltage Converter	25
Figure 4.5-1 Time of Flight Counter Construction.....	26
Figure 4.7-1 Design of an ACC Scintillator	28
Figure 4.8-1 Silicon Tracker	29
Figure 4.9-1 RICH Basic Elements	30
Figure 4.10-1 ECAL	32
Figure 4.11-1 AMS-02 Power Distribution System, Sides A and B	33
Figure 4.14-1 Proposed MMOD Shield Design	36
Figure 5.1-1 Proposed Layout of AMS-02 and CGSE Hardware in the SSPF.....	38
Figure 5.1-2 Proposed CGSE Layout at Launch Pad 1	39
Figure 5.1-3 AMS-02 Cryogenic Ground Support Equipment (CGSE) Schematic with AMS-02 Cryogenic System.....	40
Figure 5.1.1-1 System 300 – 80 K Flow Diagram.....	43
Figure 5.1.1-2 300-80K System.....	44
Figure 5.1.2-1 Master and Transfer Dewar Flow Diagram	45
Figure 5.1.2-2 CGSE Dewar (From Wessington, England)	46
Figure 5.1.3-1 Gas and Liquid Box Flow Diagram	49
Figure 5.1.3-2 Liquid Valve Box.....	50
Figure 5.1.3-3 Gas Valve Box	51
Figure 5.1.4.1-1 Leybold Vacuum Pumps	52

Figure 5.1.6-1 Flow Diagram for GHe Supply System for AMS-02 SFCL	53
Figure 5.1.6-2 GHe Supply System for AMS-02 SFCL	54
Figure 5.1.8-1 VH1 Heat Exchanger	55
Figure 5.1.9-1 PL1 Insertion Device that Connects to AMS-02 Fill Port	56
Figure 5.1.9-2 Insertion Device Connected to AMS-02 Simulator	57
Figure 5.1.10-1 Pneumatic System Diagram	58
Figure 5.1.11-1 Cryogenic and Vent Line Support Stand	59
Figure 5.1.12-1 CGSE Monitoring and Control General Scheme	60
Figure 5.1.12-2 CCGSE Control System	61
Figure 5.2.1-1 Schematic of TRD Pressure Stabilization System	62
Figure 5.2.2-1 Xenon CO ₂ Supply Filling System (CO ₂ Xenon System the Same)	64
Figure 5.3-1 Warm He Gas System GSE Schematic	64
5.5-1 GPS Simulator and Dell Notebook Computer	66
Figure 5.5-2 First Test Configuration	66
Figure 5.5-3 Second Test Configuration	66
Figure 5.7.1-1 PSS in “Low” Configuration with Upper USS-02 and Vacuum Case	69
Figure 5.7.1-2 PSS with Longitudinal Members Removed	70
Figure 5.7.1-3 Installing 1 of 4 Rail Assemblies	71
Figure 5.7.1-4 Installing 1 of 4 Brace Assemblies	72

Figure 5.7.1-5 Installing 1 of 2 Longitudinal Tie Braces	73
Figure 5.7.1-6 Installing 1 of 2 Lateral Tie Braces.....	74
Figure 5.7.1-7 Raising the Sliding Frames and the USS-02	75
Figure 5.7.1-8 Installing 1 of 4 Internal Diagonal Assemblies.....	76
Figure 5.7.1-9 Lower USS and Keel Attached to Upper USS-02	77
Figure 5.7.2-1 LUSS Shipping Assembly with LUSS and Shipping Panels	78
Figure 5.7.3-1 Primary Lifting Fixture (PLF).....	79
Figure 5.7.4-1 Multi-Purpose Lifting Fixture (MPLF).....	80
Figure 5.7.5-1 Intermediate Support Fixture (1 of 4)	81

LIST OF TABLES

Table 4.12-1 AMS-02 High Voltage or Current Sources.....	34
Table 5.8–1 AMS-Provided Electrical Equipment	82

List of Payload Unique Acronyms and Definitions

ACRONYMS AND ABBREVIATIONS

AC	alternating current
ACC	Anti-Coincidence Counters
AFD	Aft Flight Deck
AI	Action Item
AMICA	Astro Mapper for Instrument Check of Attitude
AMS	Alpha Magnetic Spectrometer
APCU	Assembly Power Converter Unit
APO	AMS Program Office
ASTC	AMICA Star Tracker Camera
AWG	American Wire Gauge
BCE	Battery Charger Electronics
BFS	Backup Flight System
BMS	Battery Management System
BOL	Beginning of Life
BD	Burst Disk or Bursting Disk
CAB	Cryomagnet Avionics Box
CAN	Controller Area Network
CAS	Common Attach System
CCD	Charged Coupling Device
CCEB	Cryocooler Electronics Box
CCR	Crew Consensus Report
CCS	Cryomagnet Current Source
CCSC	Cryomagnet Control and Signal Conditioning
CDC	Cool Down Circuit

ACRONYMS AND ABBREVIATIONS (Cont.)

ACRONYMS AND ABBREVIATIONS (Cont.)

CDD	Cryomagnet Dump Diode
CFC	Carbon Fiber Composite
CFRC	Carbon Fiber Reinforced Composite
CFRT	Carbon Fiber Reinforced Thermoplastic
CGS	Carlo Gavazzi Space
CGSE	Cryomagnet (or Cryogenic) Ground Support Equipment
CGSE-ES	CGSE Electrical System
CGSE-MS	CGSE Mechanical System
CHX	Cold Heat Exchanger
CLA	Capture Latch Assembly
CMG	Control Moment Gyro
CO ₂	Carbon Dioxide
COPV	Composite Overwrapped Pressure Vessel
COTS	Commercial Off The Shelf
CPA	Corrugated Polyallomer
CRES	Corrosion Resistant Steel
CRISA	Computadoras, Redes e Ingeniería SA
CSP	Cryomagnet Self Protection
CSR	Customer Support Room
DAQ	Data Acquisition
DC or dc	Direct Current
DDRS	Digital Data Recording System
DLCM	Direct Liquid Content Measurement Device
DOE	Department of Energy
DOL	Discrete Output Low
DV	Digital Valve
EA	Engineering Directorate
EBCS	External Berthing Camera System

ACRONYMS AND ABBREVIATIONS (Cont.)

ECAL	Electromagnetic Calorimeter
EHV	ECAL High Voltage
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESCG	Engineering and Sciences Contract Group
ESMD	Exploration Systems Mission Directorate
EOL	End of Life
EPP	Enhanced Parallel Port
ETH	Eidgenössische Technische Hochschule
EVA	Extravehicular Activity

FOD	Foreign Object Debris
FoV	Field of View
FPGA	Field Programmable Gate Array
FRGF	Flight Releasable Grapple Fixture
G	Gauss or Gas
GFE	Government Furnished Equipment
GFRP	Glass Fiber Reinforced Polymer
GHE	Ground Handling Equipment
GN&C	Guidance, Navigation and Control
GPC	General Purpose Computer
GPS	Global Positioning System
GSDP	Ground Safety Data Package
GSE	Ground Support Equipment
GSFC	Goddard Spaceflight Center
GSRP	Ground Safety Review Panel
GUI	graphical user interface

ACRONYMS AND ABBREVIATIONS (Cont.)

HBE	Hans Bieri Engineering
HP	Heat Pipe
HR	Hazard Report
HRDL	High Rate Data Link
HV	High Voltage
IA	Implementing Agreement
ICD	Interface Control Document
ID	Inside Diameter
I/F	Interface
IFM	In-flight Maintenance
IR	Infra-red
ISF	Intermediate Support Fixtures
ISIS	International Subrack Interface Standard
ISS	International Space Station
ISSP	International Space Station Program
ITS	Integrated Truss Segment
JINF	J-Crate Interface Card Designator
JMDC	J-Crate Main Data Computer
JS	Jacobs Sverdrup
K	Kelvin
KHB	KSC Hand Book
KSC	Kennedy Space Center
LBBX	Laser Beamport Box
LCC	Launch Commit Criteria
LCC	Launch Control Center
LCL	Latching Current Limiter
LCTL	Laser Control Box
LDDR	Laser Diode Driver

ACRONYMS AND ABBREVIATIONS (Cont.)

LED	Light Emitting Diode
LFCR	Laser Fiber Coupler
LGA	Gas analysis output sensor designator
LHFP	Liquid Helium Fill Port
LHP	Loop Heat Pipe
LOD	Oscillation Damper Designator
LP	Pressure Sensor Designator
LSSO	Launch Site Safety Office
LTOF	Lower Time of Flight
LUSS	Lower Unique Support Structure
LVP	Pressure Relief Valve Designator
MAGIK	Manipulator Analysis, Graphics and Integrated Kinematics
MCC	Mission Control Center
MCC	Main Control Computer
MDC	Main Data Computer
MDP	Maximum Design Pressure
MET	Mission Elapsed Time
MEOP	Maximum Expected Operation Pressure
MHT	Main Helium Tank
MIT	Massachusetts Institute of Technology
MLI	Multi-layer Insulation
MMOD	Micro-Meteoroid and Orbital Debris
MOSFET	Metal-Oxide-Silicon Field Effect Transistor
MPLF	Multi-Purpose Lifting Fixture
MV	Manually-actuated Valve
NEC	National Electric Code
NFPA	National Fire Protection Association
NSTS	National Space Transportation System

ACRONYMS AND ABBREVIATIONS (Cont.)

OD	Outside Diameter
OFHC	Oxygen Free High Conductivity
OIU	Orbiter Interface Unit
OSHA	Occupational Safety and Health Administration
P&I	Process and Instrumentation
PAS	Payload Attach System
PCS	Portable Computer System
PCU	Plasma Contractor Unit
PDA	Payload Disconnect Assembly
PDIP	Payload Data Interface Panel
PDS	Power Distribution System
PEDS	Passive Electrical Disconnect System
PEEK	Poly ether ether-ketone
PFR	Portable Foot Restraint
PFTE	poly(tetrafluoroethylene) (DuPont trade name is Teflon™)
PGSC	Payload and General Support Computer
PGT	Pistol Grip Tool
PIP	Payload Integration Plan
PLB	Payload Bay
PLC	Programmable Logic Controller
PLF	Primary Lifting Fixture
PMMA	Polymethyl Methacrylate (Plexiglas™)
PMT	Photo Multiplier Tube
PO	Payload Organization
POCC	Payload Operations Control Center
PPE	Personal Protective Equipment
PPS	Passive Phase Separator
PRLA	Payload Retention Latch Assembly

ACRONYMS AND ABBREVIATIONS (Cont.)

PSRP	Payload Safety Review Panel
PSS	Primary Support Stand
PVGF	Power Video Grapple Fixture
PVVV	Pilot Valve Vacuum Vessel
RF	Radio Frequency
RHV	RICH High Voltage
RICH	Ring Imaging Cerenkov Counter
RITF	Receiving Inspection Test Facility
ROEU	Remotely Operated Electrical Umbilical
RPCM	Remote Power Control Module
RWTH	Rheinisch-Westfälischen Technischen Hochschule (University of Technology)
SCL	Space Cryomagnetics Ltd.
SFCL	Superfluid Cooling Loop
SFHe	Super Fluid Helium
SJTU	Shanghai Jiao Tong University
SSPF	Space Station Processing Facility
STS	Space Transportation System
T0	Connector path that separates at the time of Shuttle launch
TAS	Tracker Alignment System
TBS	To Be Supplied
TCS	Thermal Control System
TeV	tera-electron volts
TOF	Time Of Flight
TPD	Tracker Power Distribution
TRD	Transition Radiation Detector
UGPD	UG Power Distribution Crate
UHVD	TRD High Voltage Distribution Boards

ACRONYMS AND ABBREVIATIONS (Cont.)

UHVG	TRD High Voltage Generation Boards
UPD	U-Crate Power Distribution Crate
UPS	Uninterruptible Power Supply
USB	Universal Serial Bus
USCM	Universal Slow Control Module
USS	Unique Support Structure
UTOF	Upper Time of Flight
VC	Vacuum Case
VCS	Vapor Cooled Shields
Xe	Xenon

Applicable Documents

<u>Document Number</u>	<u>Title</u>
KHB 1700.7C	Space Shuttle Payload Ground Safety Handbook
NSTS/ISS 13830	Payload Safety Review and Data Submittal Requirements
JSC 49978A	Phase II Flight Safety Data Package for AMS-02

1. PURPOSE

The purpose of the Ground Safety Data Package (GSDP) is to provide a safety assessment of the Alpha Magnetic Spectrometer-02 (AMS-02) and associated Ground Support Equipment (GSE) during ground operations at Kennedy Space Center (KSC) and to demonstrate compliance with the Shuttle ground safety requirements.

2 SCOPE

This document provides the results of the risk assessment performed on the AMS-02 and its GSE. The GSDP will be presented for review and approval to the Ground Safety Review Panel (GSRP).

3 MISSION SCENARIO

The AMS-02 experiment is a state-of-the-art particle physics detector being designed, constructed, tested, and operated by an international team organized under United States Department of Energy sponsorship. The AMS-02 experiment will use the unique environment of space, outside the limitation imposed by Earth's atmosphere, to advance knowledge of the universe and potentially lead to a clearer understanding of the universe's origin. Specifically, the science objectives of the AMS are to search for antimatter (anti-helium and anti-carbon) in space, dark matter (90% of the missing matter in the universe), and to study astrophysics (to understand cosmic ray propagation and confinement time in the galaxy).

4 PAYLOAD OVERVIEW

The following is a top-level review of the major components of the AMS-02 flight hardware. A detailed analysis and description of the flight hardware can be found in JSC 49978A, "Phase II Flight Safety Data Package for the Alpha Magnetic Spectrometer-02 (AMS-02)". The formal AMS-02 Phase II Flight Safety Review was held May 21-24, 2007. The AMS-02 completed its Flight Phase II Safety Review process on October 10, 2007. Figure 4-1 provides an overall view of the AMS-02 payload.

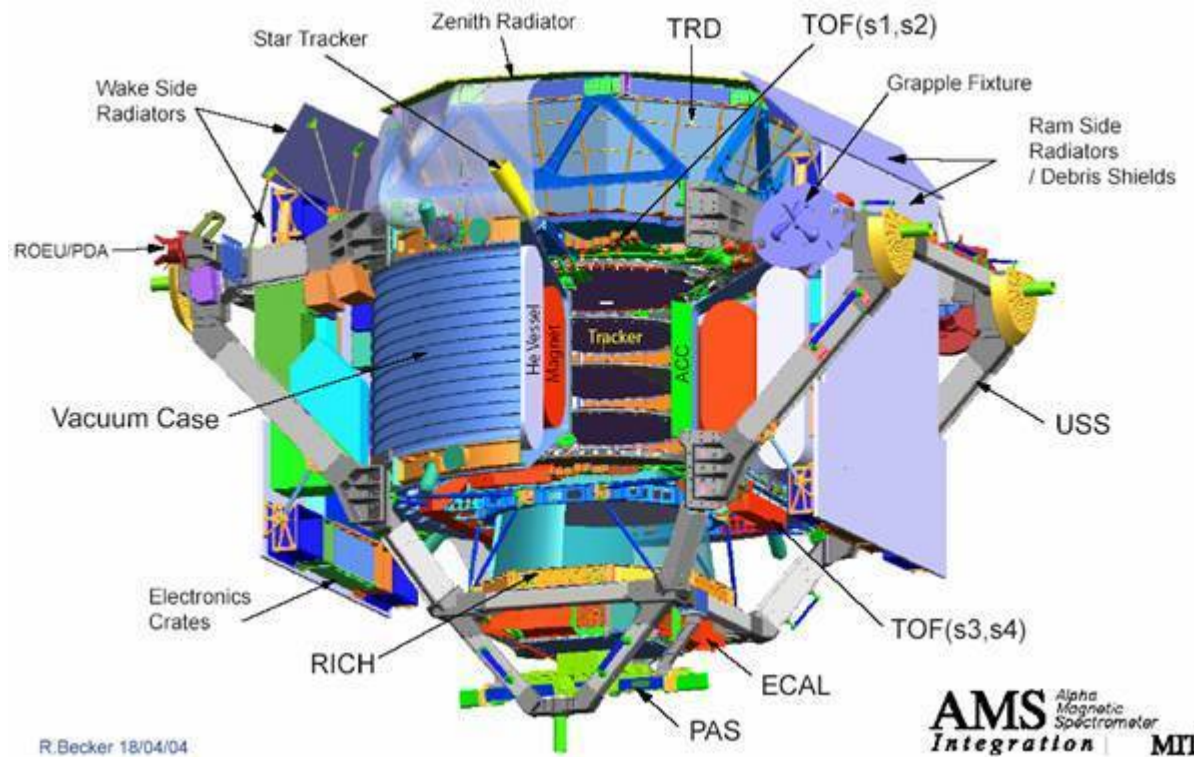


Figure 4-1 AMS-02 Flight Hardware (MLI not shown)

4.1 CRYOGENIC SUPERCONDUCTING MAGNET (CRYOMAGNET)

The Cryomagnet is at the heart of the AMS-02 experiment. Trajectories of incoming charged particles are bent by the magnetic field generated by it. The Silicon Tracker detects this trajectory, which allows AMS-02 to identify the magnitude and sign of the particles' electrical charge. The Cryomagnet has a maximum bending power of $0.86 \text{ tesla-meters squared (Tm}^2\text{)}$, which combined with the spatial resolution of the Tracker, allows measurements of particles extending into the multi-tera-electron volts (TeV) energy range. The high field strength of the Cryomagnet is possible through the use of superconductors that are chilled by a superfluid helium cryosystem serving as a heat sink operating at 1.8 Kelvin (K). Careful Cryomagnet coil design and placement minimizes the exterior magnetic field.

4.1.1 Magnetic Coils

The magnet, shown in Figure 4.1.1-1, consists of 14 coils wired in series. The primary component of the field is created by the two large dipole coils. Twelve racetrack coils further shape the field, raising the strength within the bore of the magnet to a maximum of 8600 Gauss (G) while

minimizing the stray field external to the Vacuum Case (VC). The external field has a maximum value of 2000 G at the outer surface of the VC and drops rapidly as distance increases away from the center of the AMS-02. Figure 4.1.1-2 shows the maximum strength of the field at various radii from the geometric center of the magnet. The field in the primary measurement volume and the fringe field will be mapped as part of the magnet functional testing.

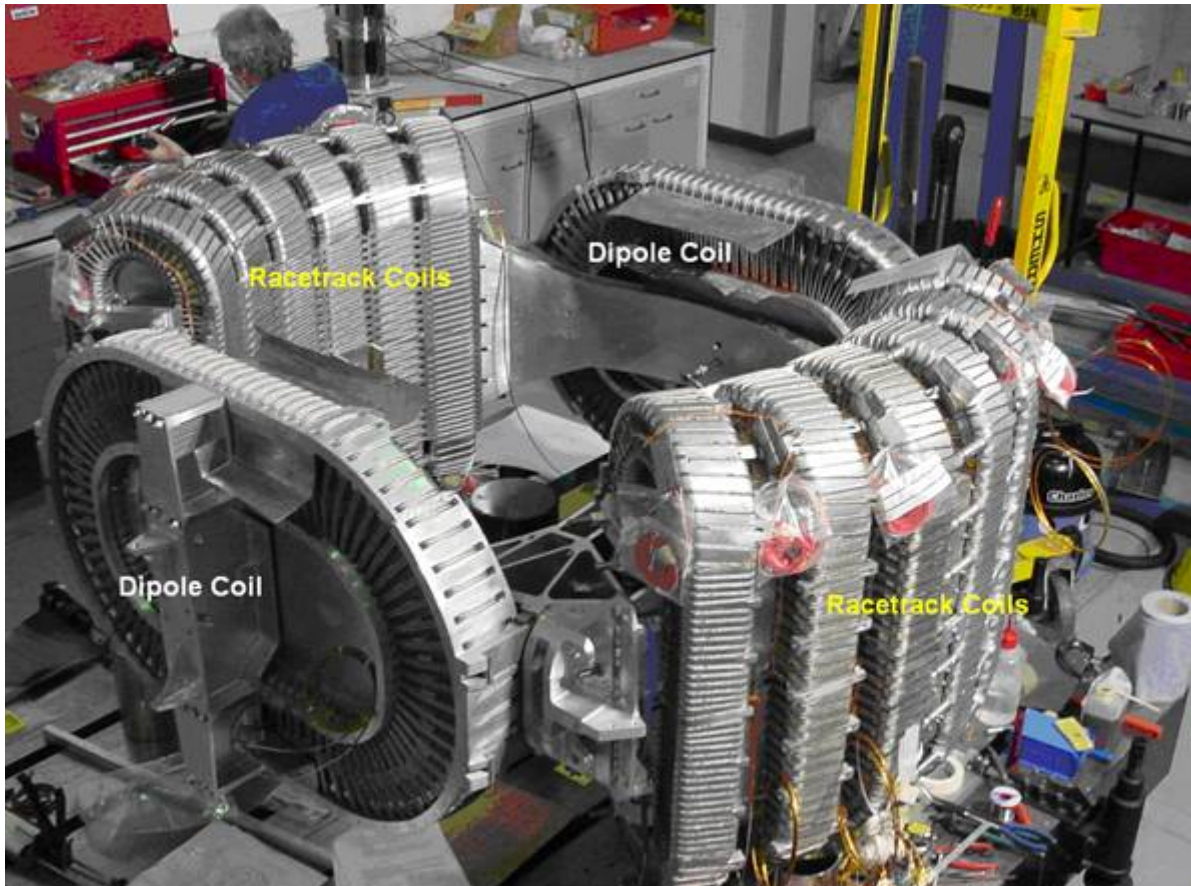


Figure 4.1.1-1 Magnetic Coils

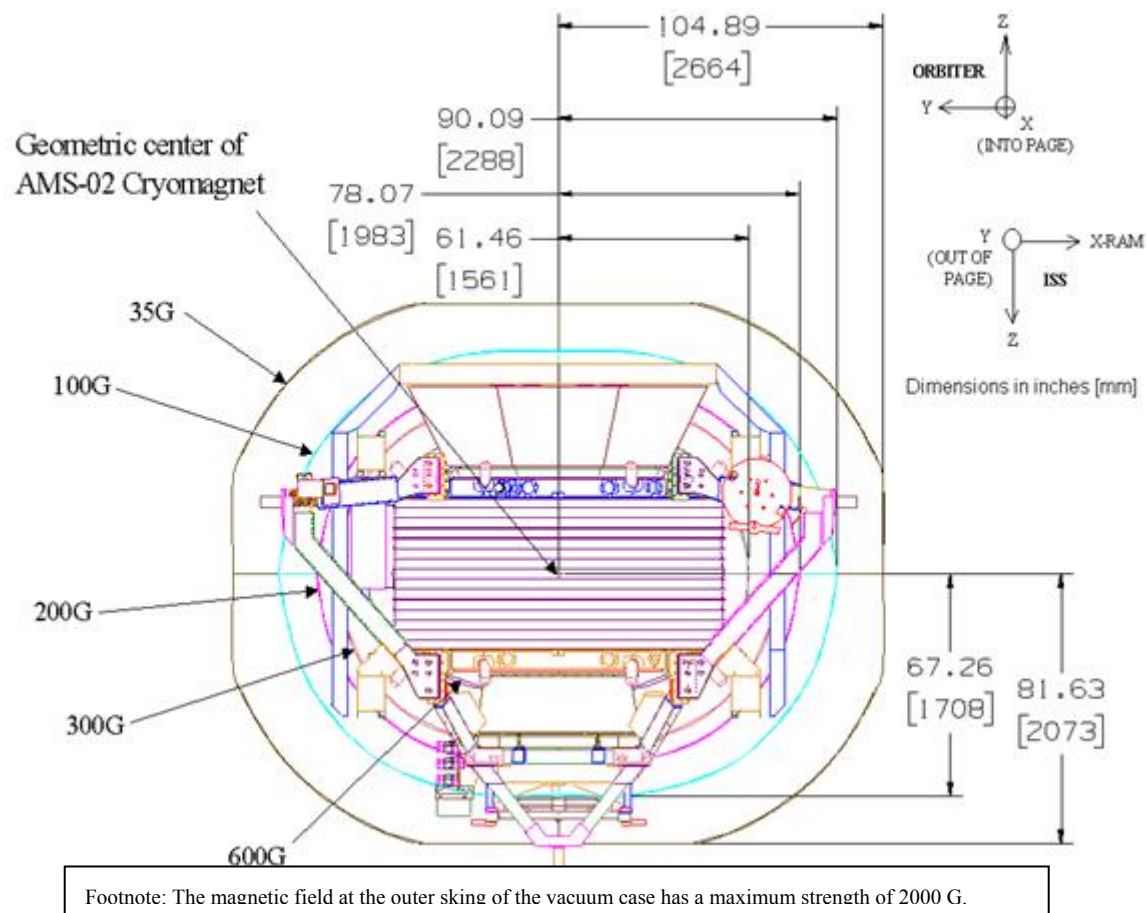


Figure 4.1.1-2 External Magnetic Field

4.1.2 Structural Support

Each coil is wrapped around a structural support made of Aluminum 6061, which keeps the coil in its elliptical shape. The large racetrack end frames seen in Figure 4.1.1-1 are also made of Aluminum 6061. These frames hold the coils in their proper relative positions and resist the magnetic forces generated when the magnet is active. These magnetic forces are on the order of 250 tons and are much larger than any other loads the magnet will see during either flight or ground operations. Since the magnet will be activated on the ground multiple times for functional testing, the flight unit will have been shown by demonstration to survive the maximum expected load conditions without deformation or damage.

The magnet is attached to the VC by sixteen support straps—which are shown in Figure 4.1.2-1. Each strap attaches to one of the VC support rings and a clevis at the corner of the racetrack end fittings. The design prevents the high magnetic operational loads from being transmitted back to

the rest of the structure and the thermal loads of the rest of the structure from being transmitted to the coils

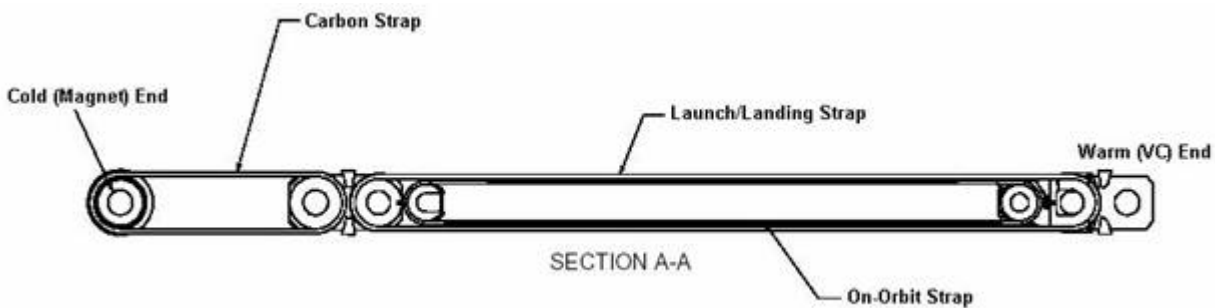


Figure 4.1.2-1 Magnet Support Strap

4.1.3 Cryogenic System

The purpose of the Cryogenic System is to maintain the temperature of the Cryomagnet coils at a temperature of 4K or below in order to keep the magnet superconductive. It also has the capability to cool the Cryomagnet after an on-orbit quench without Extravehicular Activity (EVA) support. The cryogen for this system is liquid helium, which has a high thermal conductivity when it becomes superfluid helium. It becomes a superfluid when normal liquid helium is cooled below 2.17 K.

The AMS-02 cryogenic system schematic is shown in Figure 4.1.3-1. Heat is removed from the Cryomagnet coils through the Superfluid Cooling Loop, which then conducts the heat into the main helium tank—a 2500 liter vessel. This tank contains the bulk of the cryogen used by AMS-02 and is separate from the Cryomagnet. It is at 1.8 K and is the ultimate heat sink for the entire system. As the helium slowly boils away, vapor is removed from the system and flows through a series of four vapor cooled shields operating between 1.8K and 60K which surround the Cryomagnet assembly. Small thermal connections run between these shields and the metallic fittings on the support straps to further reduce the heat leak into the main tank from the structural supports. The outermost vapor-cooled shield is thermally attached to four cryocoolers, which further reduce the overall temperature and slow the rate of helium loss. In flight the helium is then released through a zero-thrust vent. During ground processing, it is exhausted to one of two vacuum pumps, either an on-board pump for short durations (e.g., between L-88 hours and L-30 minutes) or, for longer durations, a large GSE Roots pump.

The following is a breakdown of the major components of the cryogenic system. For more information, refer to the AMS-02 Flight Safety Data Package, JSC 49978A.

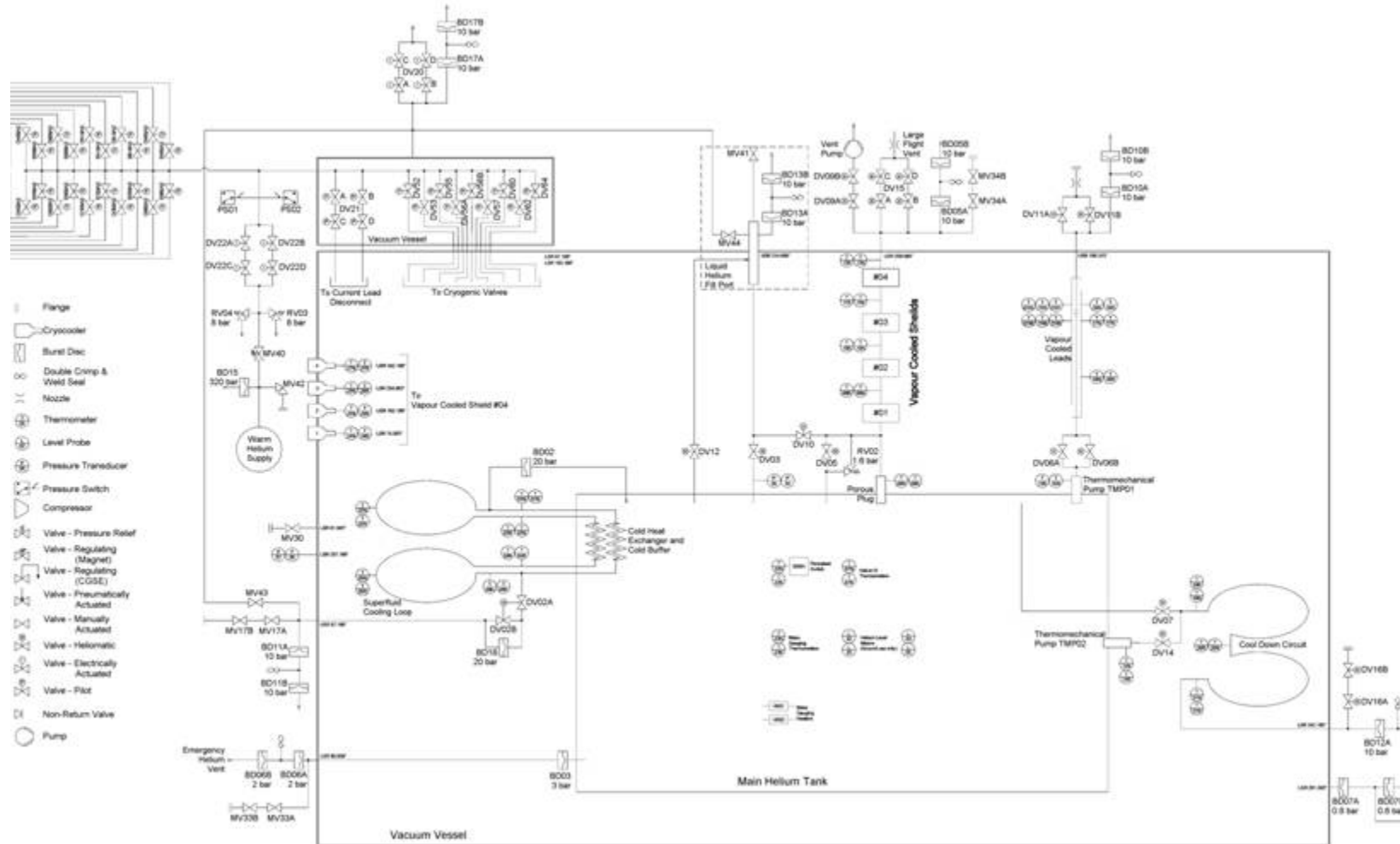


Figure 4.1.3-1 AMS-02 Cryogenic Schematic

4.1.3.1 Coil Cooling

Each Cryomagnet coil has two thermal shunts attached to the Superfluid Cooling Loop, which runs along the top and bottom of the magnet. The loop is a copper pipe filled with superfluid helium. Heat in the coils is conducted through the shunt into the liquid inside the loop. The cooling loop in turn extends into the main helium tank where a serpentine heat exchanger (Figure 4.1.3.1-1) dissipates the heat into the superfluid helium.

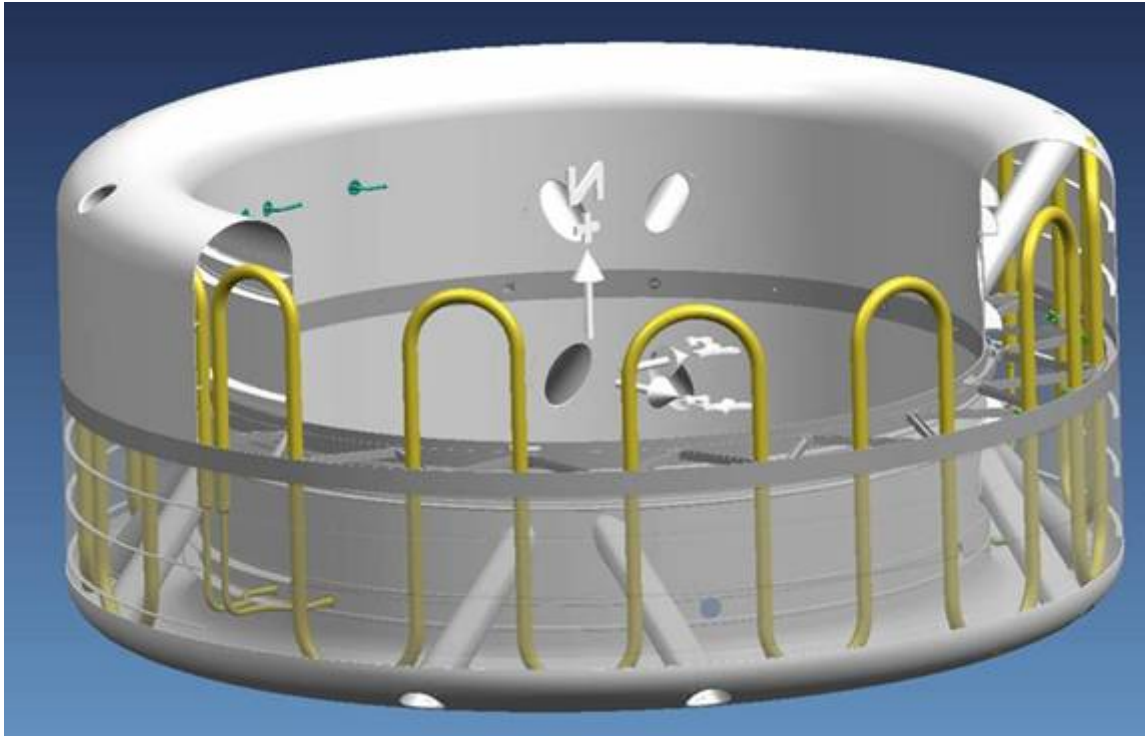


Figure 4.1.3.1-1 Heat Exchanger

The Superfluid Cooling Loop (SFCL) is filled on the ground through valve DV02 and MV17A and B, which are then closed on the ground and never reopened (Filling of the SFCL is accomplished prior to arriving at KSC). This loop has been designed to a maximum design pressure of 20 bar and is protected from over-pressurization by Burst Disk BD02. This disk vents the loop into the main helium tank, not externally. Since the volume expansion presents no significant pressure rise to the tank, it presents no safety hazard. For this reason, only one disk has been used.

4.1.3.2 Helium Tank

The main helium tank (Figure 4.1.3.2-1) is a 2,500 liter toroidal vessel which contains the bulk of the cryogen used by AMS-02. As shown in Figure 4.1.3.2-1, the tank consists of a central support

ring attached to two rib-stiffened cylinders. The inner cylinder has a radius of 0.96 meters and the outer cylinder has a radius of 1.29 meters. The tank is made up of aluminum 5083 forgings and all interfaces are welded. The construction technique used to fabricate the tank optimizes its ability to withstand helium permeation of the aluminum by careful control of the material grain orientation. Cryo effects on the materials used in the construction of the helium tank were taken into account during its design. The tank has been designed to a maximum positive pressure of 3 bar and a maximum negative pressure of 1 bar. The maximum pressure is ensured through three burst disks (BD's), two set to 3 bar (BD03 and BD06A) and one set to 2 bar (BD06B).

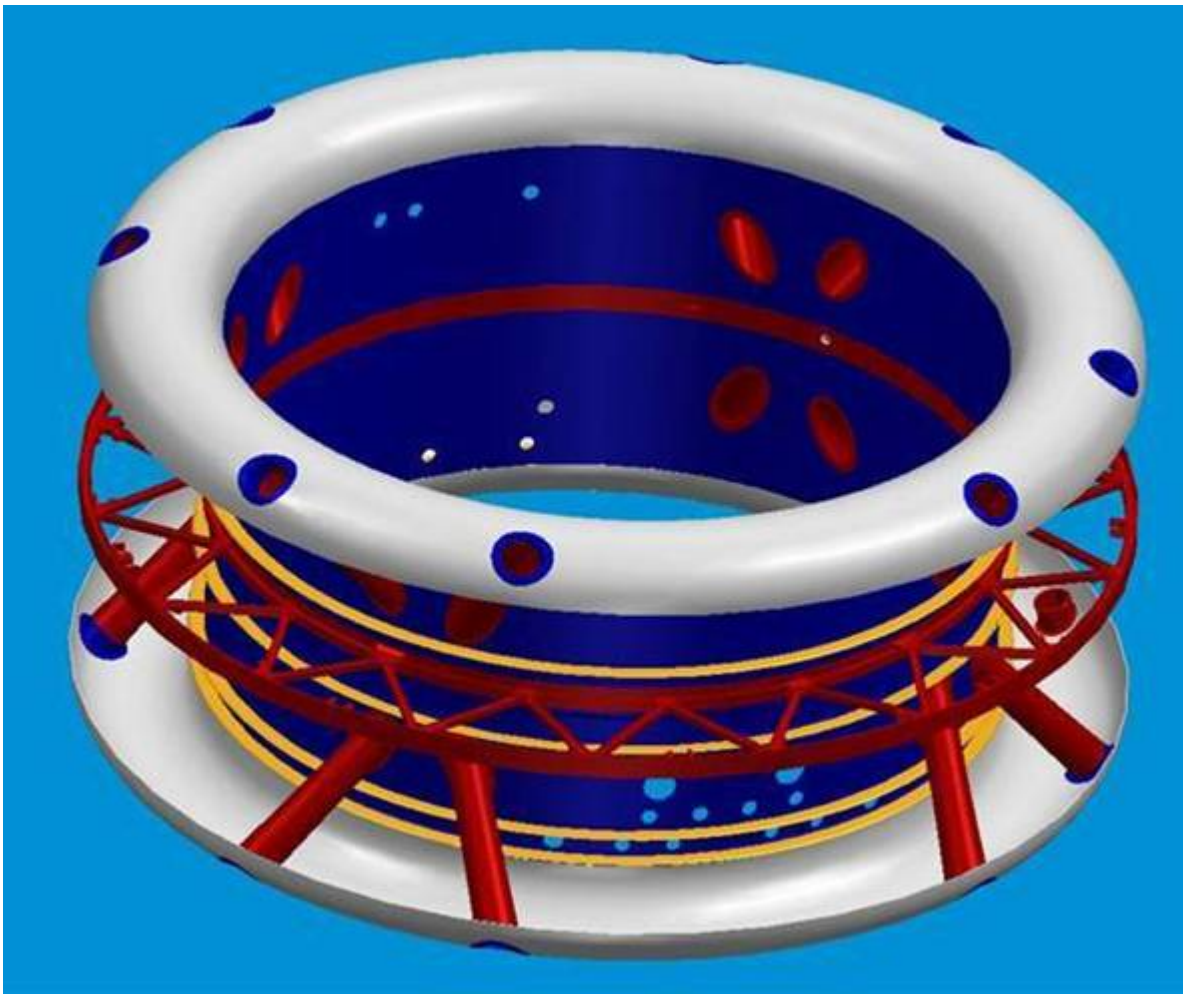


Figure 4.1.3.2-1 Helium Tank (Outer Cylinder Not Shown)

4.1.3.3 Vapor Cooled Shields (VCS)

As heat is dissipated into the main helium tank, the vapor generated is separated from the liquid by means of a porous plug. This vapor then flows into small tubes inside a series of four VCS's.

These shields surround the magnet and helium tank assembly. They are connected via small thermal shunts to the metallic portions of the support strap assemblies. These intermediate heat sinks reduce the overall heat leak into the helium tank itself and greatly increase the overall endurance of the system. The shields are thin foils of nearly pure aluminum. Two shields have carbon fiber honeycomb structures underlying them for additional structural support. As with the helium tank, each shield has sixteen holes to allow passage of the support straps.



Figure 4.1.3.3-1 Vapor Cooled Shield Structural Support

4.1.3.4 Cryocoolers

The final stage of the magnet thermal control system is four Stirling-cycle cryocoolers which attach to the outermost VCS. Together they remove approximately 12W of heat from the system. This

additional temperature drop reduces helium consumption by a factor of four. After this final cooling, the helium gas is allowed to vent to space from a zero-thrust vent aligned with the ISS Y-axis.

4.2 Vacuum Case

The VC serves a dual purpose; it is a primary structural support that works in conjunction with the Unique Support Structure (USS-02) to form the foundation structure of the AMS-02 and also serves as the outer surface of the superfluid helium dewar enclosing the main helium tank and the Cryomagnet. The VC attaches to the USS-02 at the eight interface plates and the two clevis plates. The VC assembly is shown in Figure 4.2-1

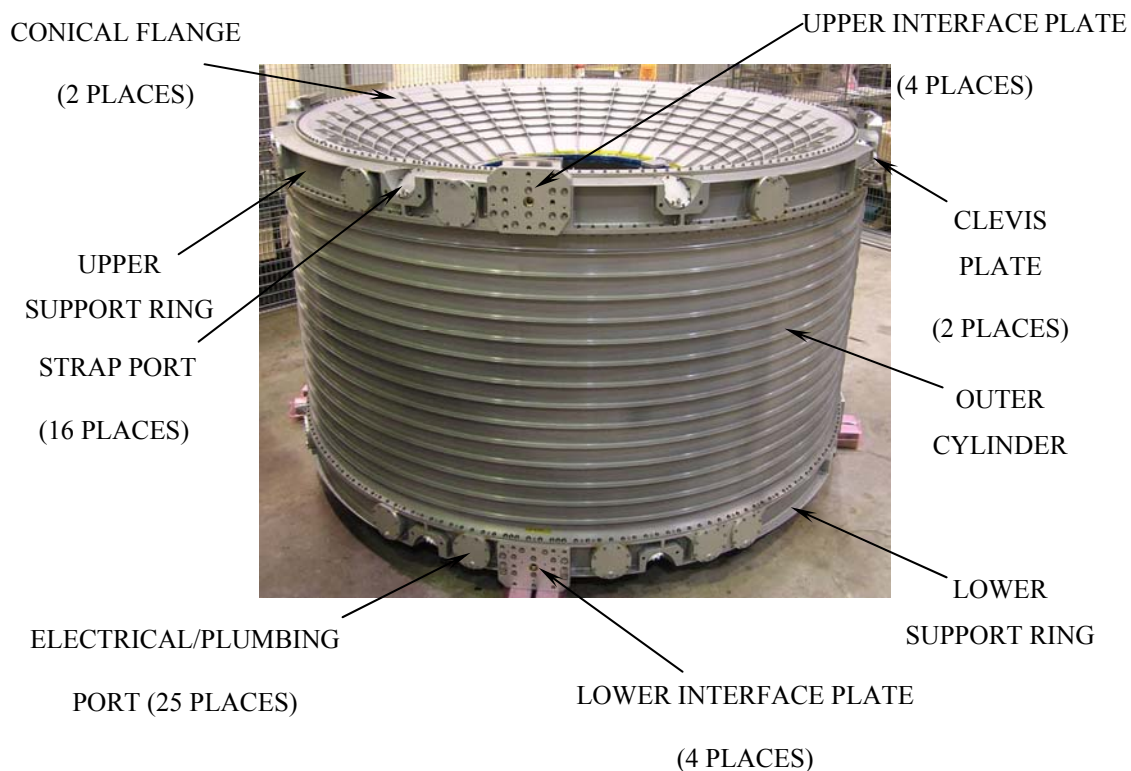


Figure 4.2-1 Vacuum Case

4.3 Unique Support Structure-02 (USS-02)

The USS-02 is the primary structural element of the AMS-02 payload. Its purpose is to structurally support the Cryomagnet and the AMS-02 experiment during launch, landing, and on-orbit loading

and integrates them with Shuttle and ISS. Figure 4.3-1 shows the USS-02 attached to the VC of AMS-02.

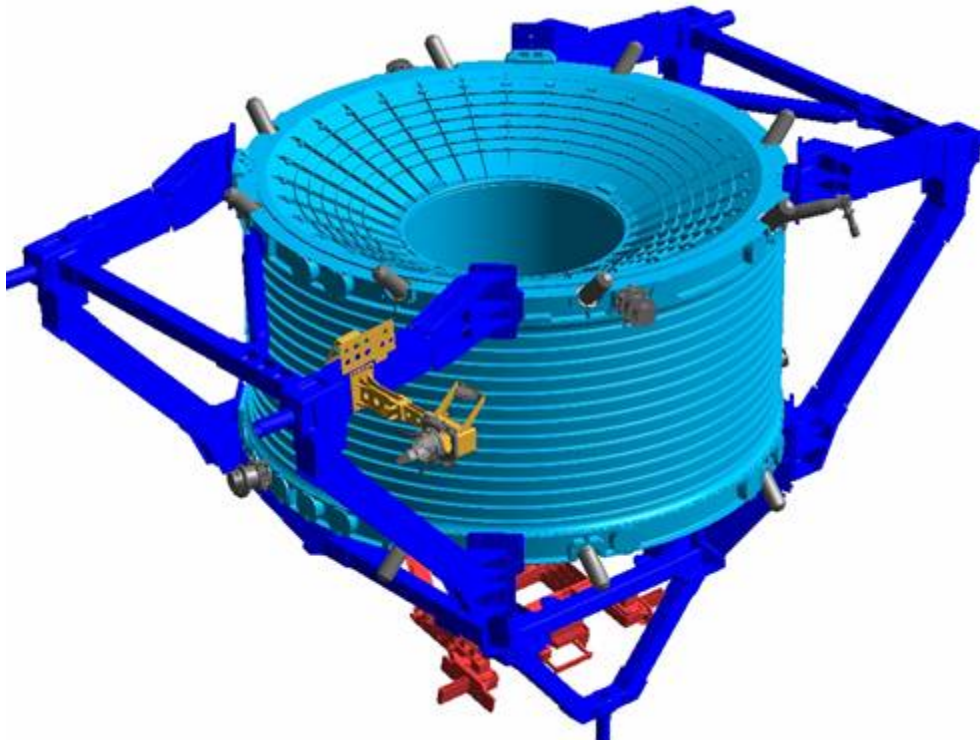


Figure 4.3-1 USS-02 Attached to Vacuum Case

4.4 Transition Radiation Detector (TRD) and Associated Gas System

The role of the TRD is to discriminate between electrons/anti-protons and positrons/protons. This is accomplished by detecting X-ray photons emitted by electrons and positrons when they pass through a radiator. As this effect depends on the velocity of the particle, it is used to discriminate against heavier particles. The radiation is detected by .001" gold-plated tungsten wires in tubes filled with xenon (Xe) and carbon dioxide (CO₂) gas in an 80:20 ratio.

4.4.1 TRD Structure

The TRD detector (Figure 4.4.1-1) is composed of 5248 proportional tubes which are made from a multi-layer wound composite structure. The composite includes layers of polyurethane, carbon-polyimide, aluminum, and Kapton. The straw tubes are grouped into 10 separate segments which are connected through gas manifolds. The straws have an inner diameter of 0.24", a wall thickness of 0.003", and vary in length from 31.5" to 78.7" (See Figure 4.4.1-2 for straw wall composition).

A straw module consists of 16 straws glued together with six stiffeners running alongside the straws. Every 3.94", additional stiffeners are glued across the module for extra rigidity. The straw ends are glued into polycarbonate end pieces. The end pieces contain the wire fixation pieces, the gas distributor, and the gas seal. These straws operate at very low pressure and will be protected from negative pressure during the majority of ground operations by GSE-supplied gas.

The TRD is constructed from 20 layers of the straw modules. The gap of 0.91" between the layers is filled with a polypropylene fleece which forms the radiator required by the detector. The upper four layers (72 modules) and the lower four layers (56 modules) are oriented in the X direction and the 12 middle layers (200 modules) in the payload Y-direction.

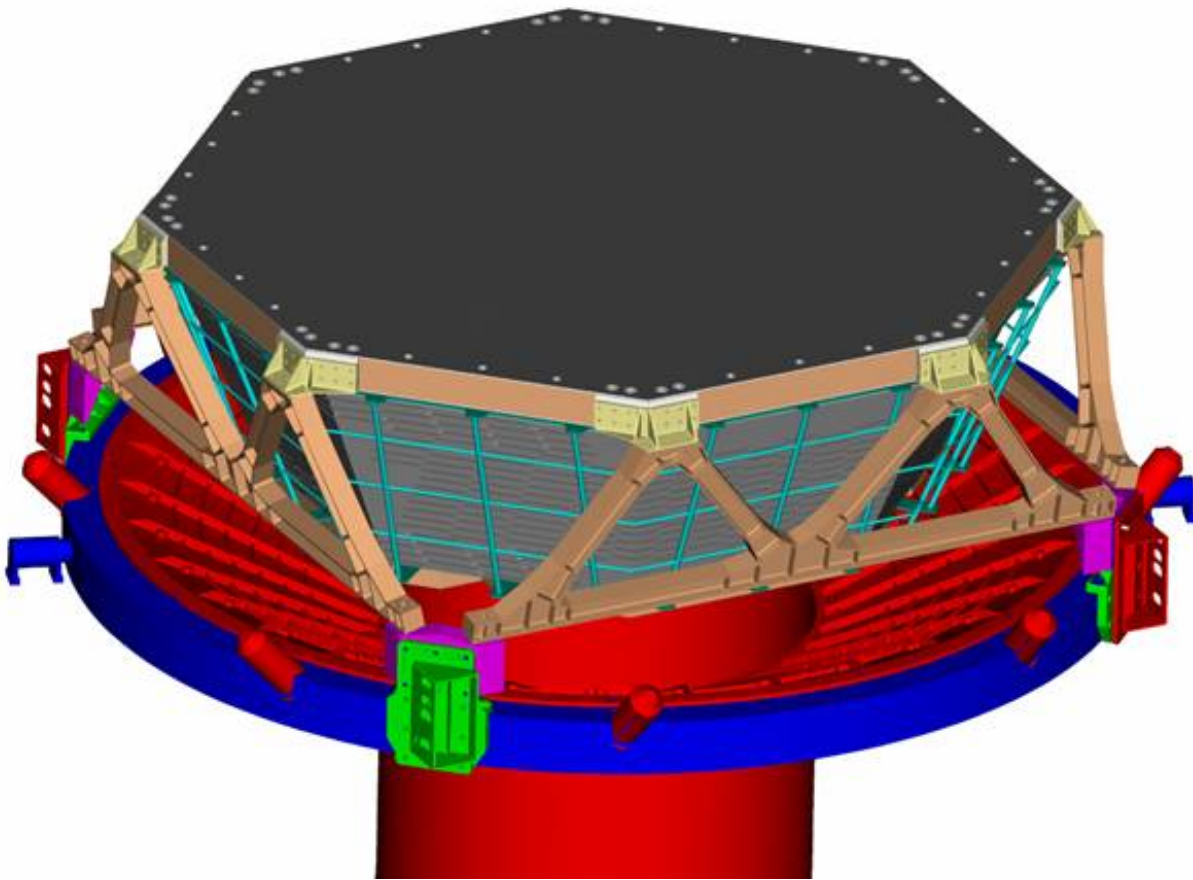


Figure 4.4.1-1 TRD Structure

The 20 layers of straw modules and radiators are mounted in an octagon structure which consists of eight honeycomb side panels [1.18" thick], a lower honeycomb support plate, and an upper honeycomb plate. The size of the octagon structure is 91" x 24.5". The combined weight of the

TRD is 742.3 lbs. Inside the octagon structure, the straw modules are further supported by four 0.1”thick bulkheads, two in the Y-direction and four smaller ones in the X-direction.

The TRD is located at the top of the experiment stack, just above the Upper Time of Flight (UTOF). The octagon structure is supported by the M-Structure, which is mounted to the USS-02 at four locations on the upper USS-02 just above the VC interface.

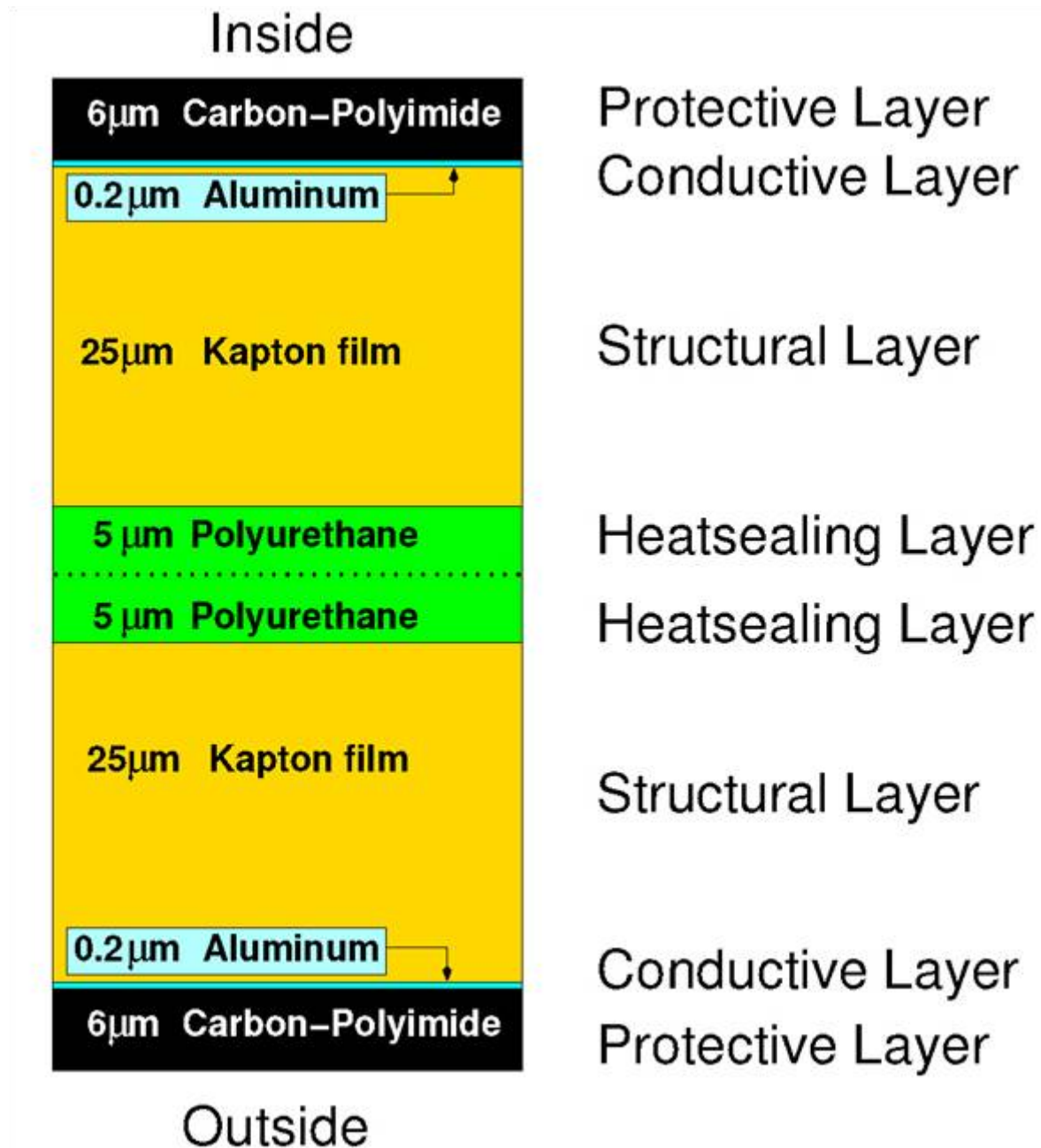


Figure 4.4.1-2 Composition of Straw Wall

4.4.2 TRD Gas Supply System

The TRD Gas Supply System (Figure 4.4.2-1) supplies a mixture of 80% Xe and 20% CO₂. The density and purity of the gas mixture is monitored and adjusted to ensure efficient detection. The gas supply system includes three tanks: one for the Xe, one for the CO₂, and one mixing tank (Figures 4.4.2-2 and 4.4.2-3). These tanks are mounted to a support bracket and covered by shields to protect them from orbital debris. The support bracket is mounted to the wake side of the USS-02 which also helps protect them from debris.

The Xe tank is a composite over-wrapped stainless steel tank that is designed and built by Arde, Inc. This tank is identical to the one used on the Plasma Contactor Unit (PCU) for ISS. It has a maximum design pressure of 3000 psid during flight with a minimum temperature rating of –60°F and a maximum temperature rating of 150°F (tank rating, not Maximum Design Pressure (MDP) temperature). The tank is designed with a proof test factor of 1.5 x MDP and a minimum burst factor of 3.1 x MDP. It has an outside diameter of 15.4” (390 mm) and a volume of 1680 cubic inches (27.5 liters). It carries a maximum of 99 lbs (45 Kg) of Xe at launch and has been tested to 8.9 Grms at 0.08 g²/Hz.

The CO₂ tank is also a composite over-wrapped stainless steel tank designed and built by Arde, Inc. This tank was designed for use on the X-33 vehicle and has a maximum design pressure of 3000 psid with a minimum operating temperature of –100°F and a maximum operating temperature of 300°F (tank capabilities, not AMS-02 application). The tank -is designed with a proof test factor of 1.5 x MDP and a minimum burst factor of 2.125 x MDP. MDP is only under worst-case on-orbit temperature exposure. The outside diameter is 12.4” (315 mm) and it has a volume of 813 cubic inches (13.3 liters). The tank weighs 9.5 lbs (4.3 kg) and is designed to hold a maximum of 11 lbs (5.0 kg) of CO₂. A vibration test has been performed to 8.9 Grms at 0.07 g²/Hz axially and 4.5 Grms at 0.02 g²/Hz laterally.

The small, stainless steel mixing tank, was also manufactured by Arde, Inc. It has a nominal operating pressure of 200 psia, a normal operating temperature of 77°F and an MDP of 300 psid established by dual pressure relief devices and the source gas supply control. A proof test factor of 1.5 x MDP and a minimum burst factor of 4 x MDP has been used. The volume is 61 cubic inches (1 liter).

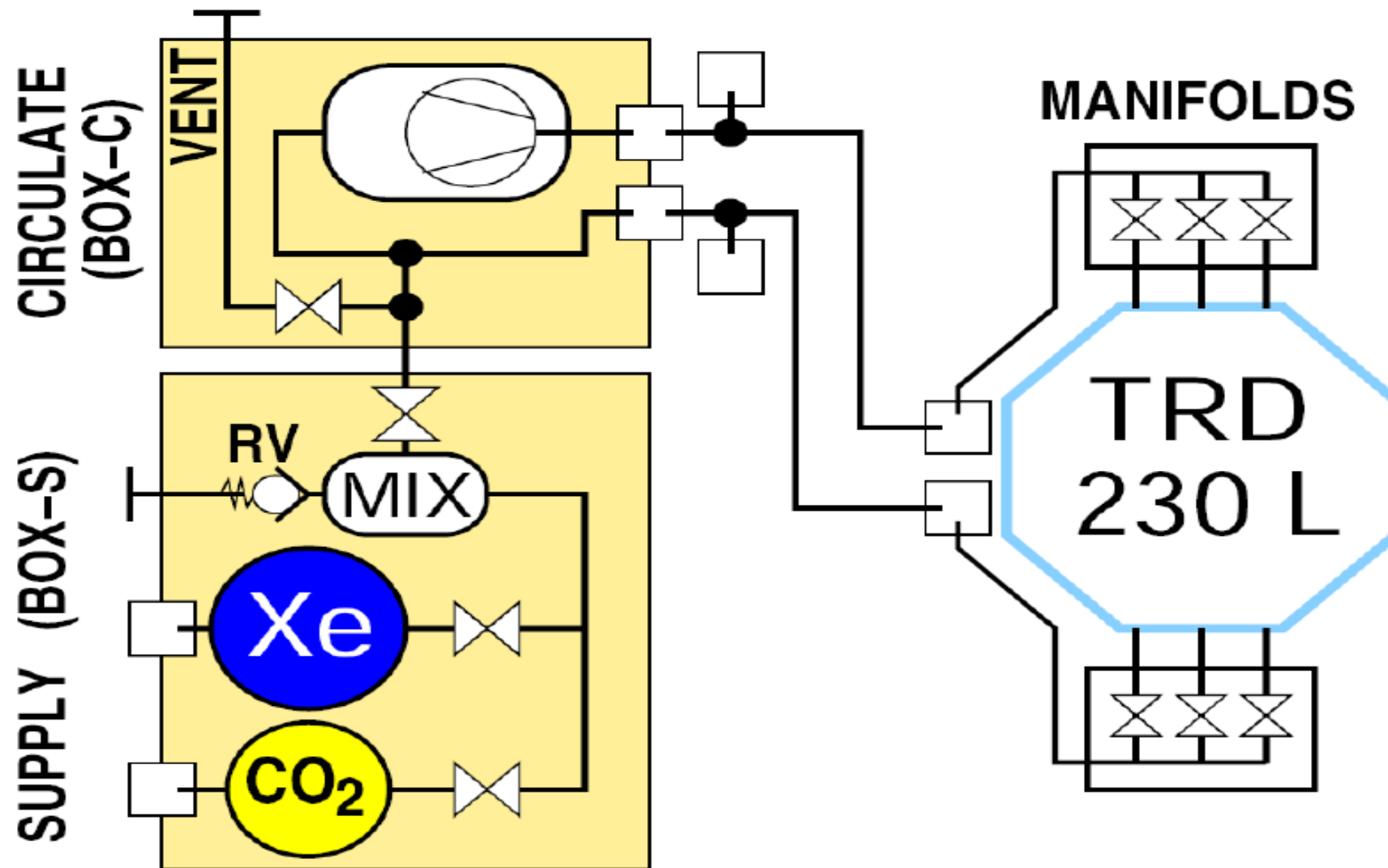


Figure 4.4.2-1 Schematic of TRD Gas Supply System

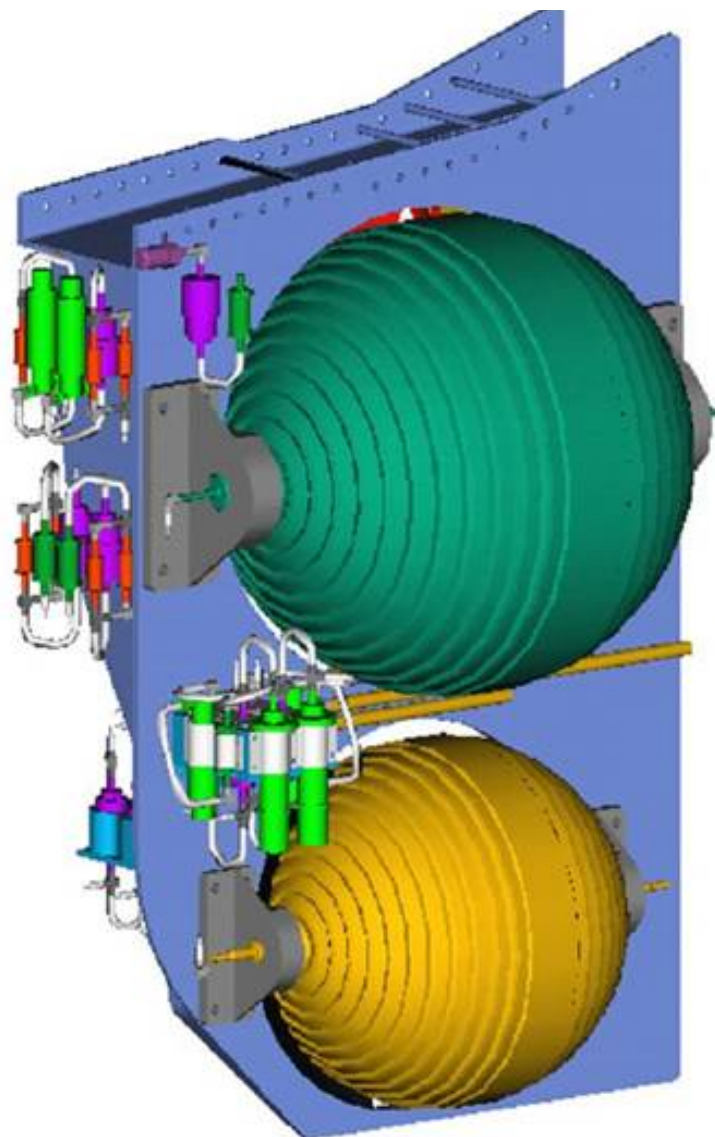


Figure 4.4.2-2 TRD Gas Supply System

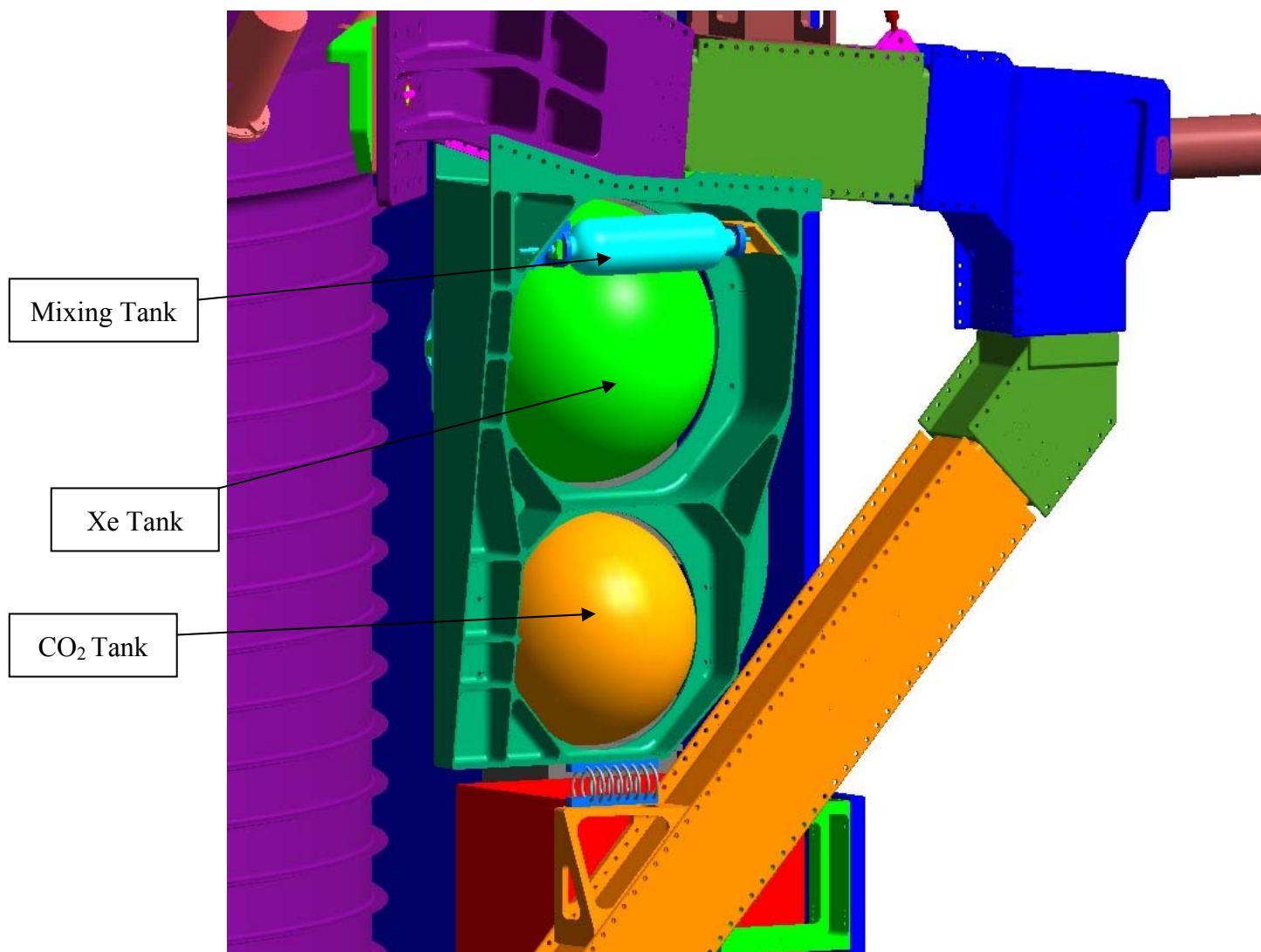


Figure 4.4.2-3 TRD Gas Supply System (Box S) as Mounted on USS Structure(With Outer Debris Shield Removed)

There are two sections to the TRD gas system, a Box S and a Box C. Box S contains all the high pressure elements, Box C and the TRD itself operate at pressures just above 1 atm. Descriptions of both sections follow.

4.4.2.1 Box S Description

Box S, shown in Figure 4.4.2.1-1, contains the gas reserves for the TRD. Gas is released from the two reservoirs into the mixing vessel (D), where it is combined in the required ratio and stored until such time as the straw tubes need to be replenished. The combined gas is transferred to Box C for circulation as needed.

The reservoirs are filled through fill ports with different GSE threads to make interchange impossible. If performance is as desired, then each of the fill ports are capped with two independent caps with metal seals.

Maximum design pressure for the gas reservoirs, the buffer volumes, and the associated piping through valves V3a and V3b have been determined through thermal analysis and all items have been shown to have sufficient structural margin. MDP of the mixing vessel and all plumbing between V3a/V3b and V4a/V4b is set at 300 psi based on the redundant burst disks shown in Figure 4.4.2.1-1. This hardware has also been shown to have adequate margin through structural analysis.

Box S Schematic

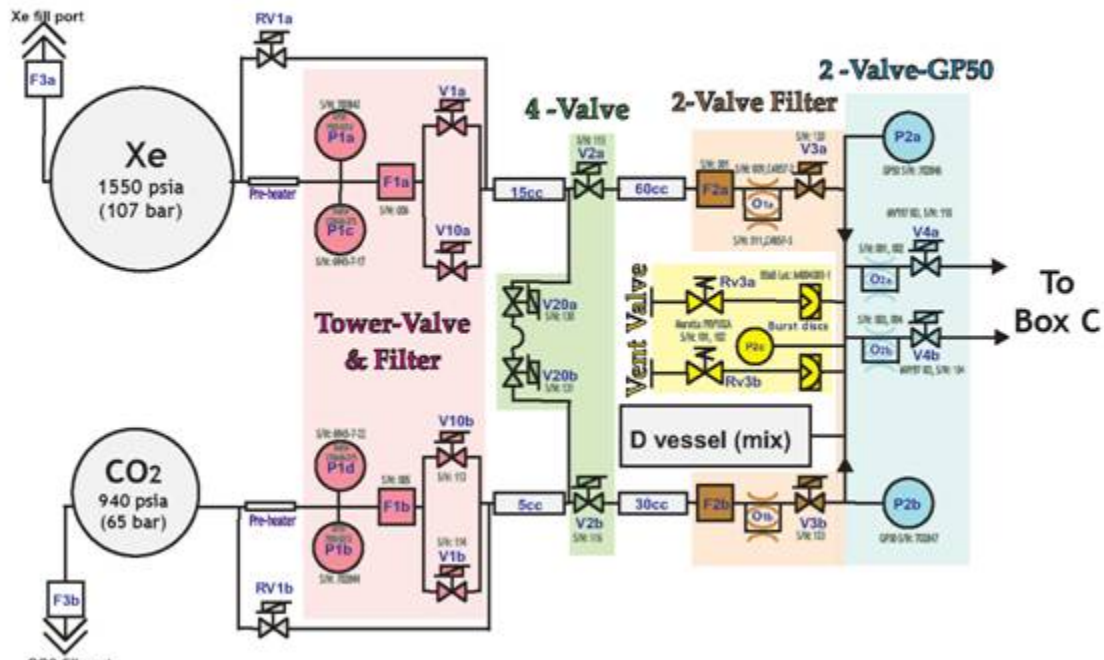


Figure 4.4.2.1-1 Box S Schematic

4.4.2.2 Box C Description

Box C, shown in Figure 4.4.2.2-1, contains the pumps which circulate the gas throughout the TRD. Pumping the gas after refreshment through each of the TRD's 328 straw modules prevents the gas from separating into pockets and ensures uniform properties. Box C is mounted on the USS-02 just above the main TRD Gas Supply.

Newly mixed gas from Box S arrives in Box C through valves V6A or V6b. Here it merges with the gas circulating through the TRD. Next, the gas enters the canister (pressurized at 2 bar), where two KNF Neuberger UNMP30 pumps provide the circulation through the system. These pumps operate in the open environment of the canister, with only one side of the pump connected directly to the plumbing. Only one pump is needed – the redundant pump is for mission success. Inside the canister the gas flows through an ultrasonic spirometer, which measures the CO₂ in the gas flow and provides an independent check of the Xe/CO₂ ratio. The gas then flows back into the manifolds and re-enters the straw tubes.

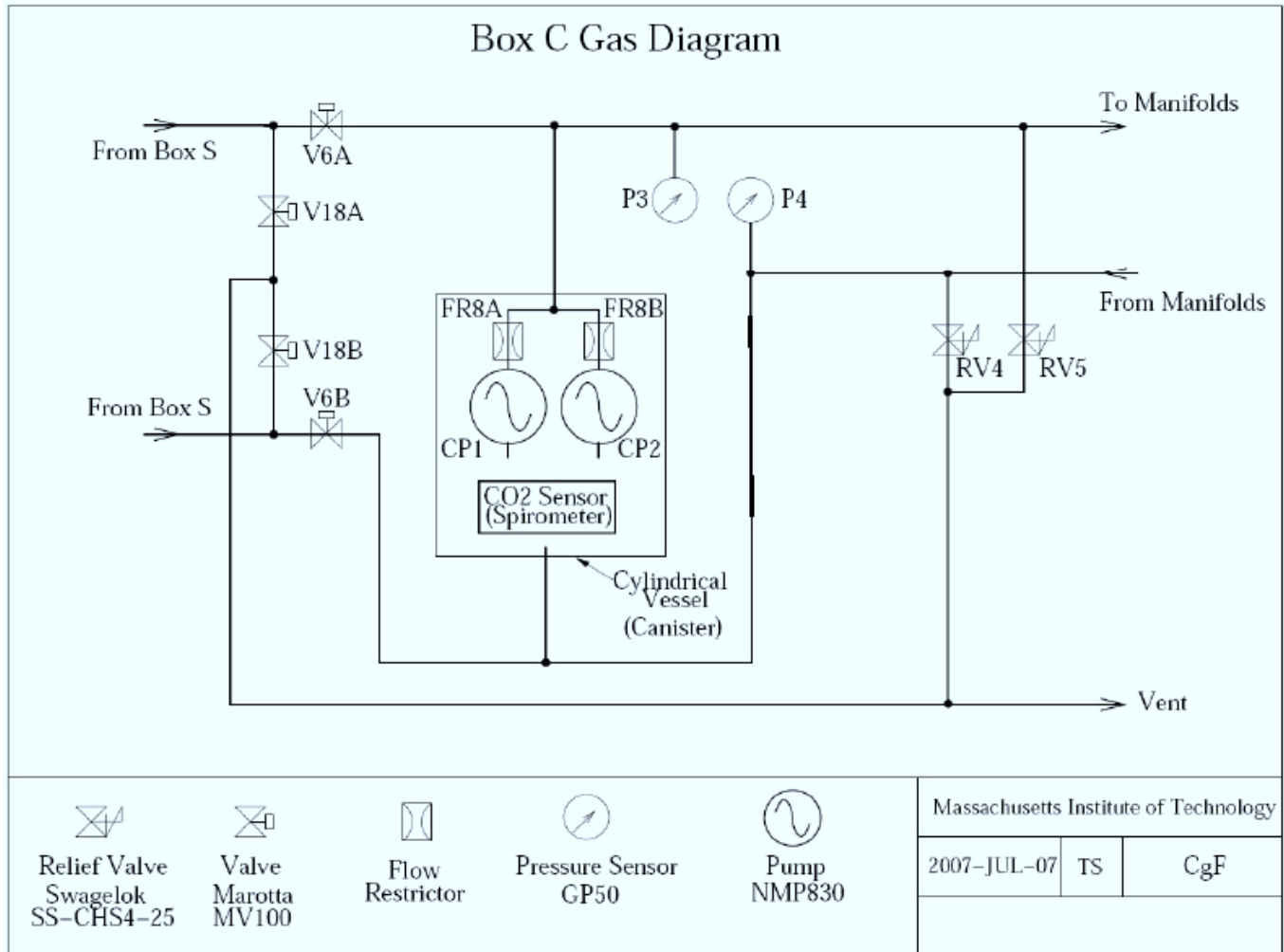


Figure 4.4.2.2-1 Box C Schematic

4.4.2.3 Straw Tube Segments

From Box C, 3 mm stainless steel gas lines run to the top rim of the TRD, where input and output manifolds are located. The 5248 tubes of the TRD are grouped into ten distinct segments; each separately attached to input and output manifolds (Figure 4.4.2.3-1). Each segment is small enough so as not to be considered a pressure vessel (1 bar x 28 liters=2.8 kJ) Each manifold line is connected to four TRD segments via pressure controlled isolation valves. Steel tubing—which is 0.06”—runs from the isolation valves to the segment inputs and outputs, where it is joined to the straws via special connectors designed by Rheinisch-Westfälischen Technischen Hochschule (RWTH) in Aachen. Cajon fittings are used where other connections need to be made. The straw manifolds are extremely sensitive. In order to maintain their ability to achieve their science goals, they will be protected against possible negative pressure by introducing a steady flow of a Xe/CO₂ mixture pressure slightly above 1 atm through the tubes.

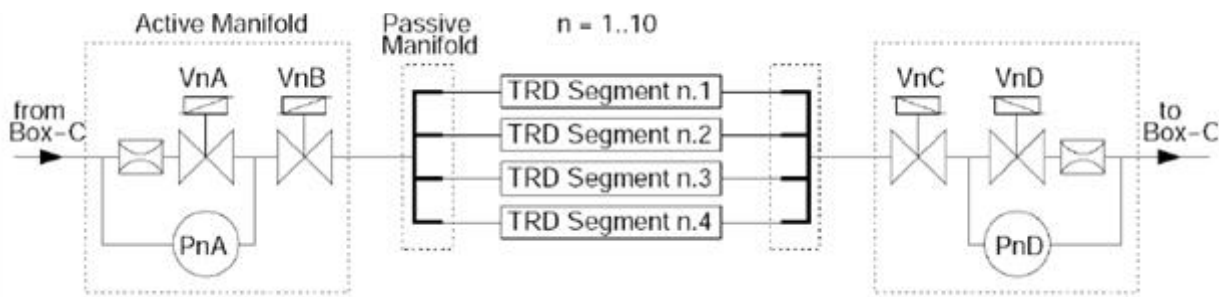


Figure 4.4.2.3-1 One of the 10 TRD Straw Tube Segments

4.4.2.4 Monitoring and Control

The electronics that control the gas system are located in the UG-crate. This crate will contain a Universal Slow Control Module (USCM) computer that manages the monitoring and control tasks, as well as maintain communication with the AMS-02 Main Computer (J-Crate Main Data Computer (JMDC)). The USCM is provided with interface electronics to the various gas transducers and actuators scattered throughout the gas system. The USCM and interface electronics will perform the following tasks:

- Close or open emergency isolation valves in the manifolds.
- Provide housekeeping data (temperature of valves, pressure vessels, etc.)

- Store calibration constants.
- Condition and perform analog to digital conversion for 29 pressure sensors and approximately 500 temperature sensors distributed around the TRD and gas system.
- Control two recirculation pumps.
- Provide logic control for approximately 56 gas valves.
- Provide the power electronics to drive valves, etc.
- Read out digital signals from the gas analyzer (spirometer). Switch the gas system to “Safe Mode” (for mission success) in case of communication failure.

The USCM, interface electronics, and calibration tubes are doubled to provide single fault tolerance for mission success. The USCM does not require or use batteries. If there is a power failure, the pumps stop, and all the Marotta valves close (they require power and commands to open). This ensures that the Xe and CO₂ gas tanks are sealed, and that no gas is transferred, either within Box S (e.g. to the mixing tank or other sealed volumes) or from Box S to Box C and the rest of the gas system. All mechanical safety release valves, for overpressure, remain operational. All of the flipper valves, which are used to isolate individual sectors of the gas system in case of leak, and to choose which pump is in-line with the overall gas circuit, remain in whatever state they were when power went off. This means that, on-orbit, if there is a leak which develops in the TRD when power is off, the worst that would happen is that it would slowly lose the approximately 230 liters of gas in the TRD, which is small compared to the 10,000 liters of gas in the Xe and CO₂ tanks. Any sector previously isolated because of a leak would remain isolated. On the ground, a leak with power off would slowly contaminate the gas in the TRD with air so that it would not work well when power was switched on again, but would have no safety impact.

The TRD High Voltage (HV) system consists of High Voltage Generation Board (UHVG) with six each located in the two U-crates controlled by the J-Crate Interface Card Designator (JINF). Each UHVG card drives seven HV lines with twofold internal redundancy to provide single fault tolerance for mission success. Each line is connected via shielded HV cabling to a HV distribution board (High Voltage Distribution Boards (UHVD)) mounted on the octagon in the vicinity of the readout cards to distribute the HV to four modules (64 tubes). The schematic of the HV system is

shown in Figures 4.4.2.4-1 and 4.4.2.4-2. Each unit provides +1600V (control range: 700-1750V) with current limited to <100 microamperes.

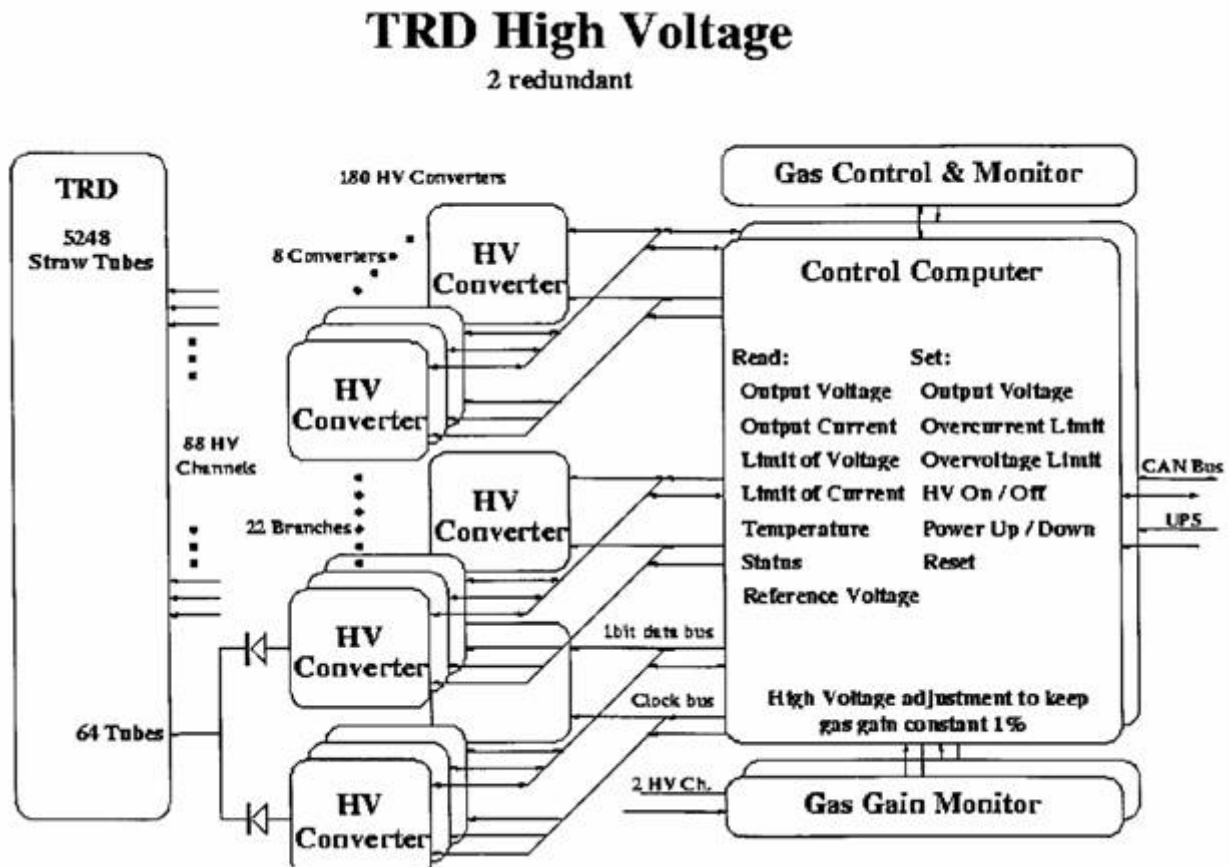


Figure 4.4.2.4-1 High Voltage System

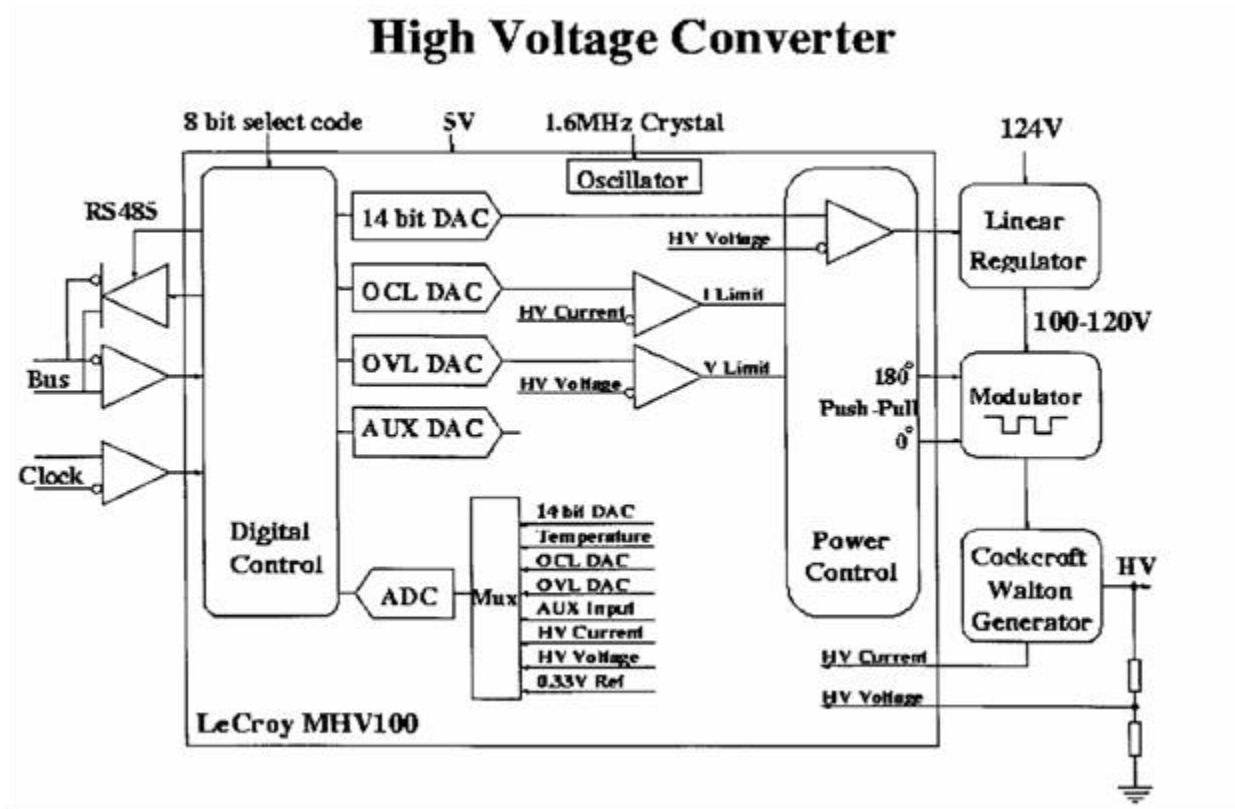


Figure 4.4.2.4-2 High Voltage Converter

4.5 Time of Flight (TOF) Scintillator Counters

The TOF serves to: 1) be a fast trigger to the experiment for traversal of a particle across the bore of Cryomagnet and Silicon Tracker, 2) distinguish between upward and downward traveling particles, and 3) measure the absolute charge of the particle. Particles that pass through the scintillators generate photons as they pass through the counter paddles, and these photons are detected by groups of two or three sensitive Photo Multiplier Tubes (PMT's) on either end of the detector element, the counter paddles.

The TOF is composed of four planes of detectors, two atop the AMS tracker, two below as shown in Figure 4.5-1. Numbered from the top down, detector assemblies 1, 2, and 4 have eight detector paddles per plane and detector assembly 3 has ten. The pairs of detector assemblies are oriented 90° to each other. This configuration gives a 12 x 12 cm² resolution for triggering particle events over the 1.2 m² area the TOF covers.

Each individual detector paddle is made of polyvinyl toluene (a Plexiglas-like material) that is 12 cm wide and 10 mm thick. End paddles of each layer are trapezoidal with a width of 18.5 cm to

26.9 cm. Each detector paddle is wrapped in aluminized Mylar and enclosed in a cover made of carbon fiber. Each detector paddle includes a depressurization pipe to allow for pressure equalization. In the center of each detector is a LED that is used for calibration and testing. At the ends of each panel are light guides which direct the light of scintillation to photo multipliers. These light guides are curved to orient the photomultiplier tubes within the AMS-02 magnetic field for minimum impact to photomultiplier operations.

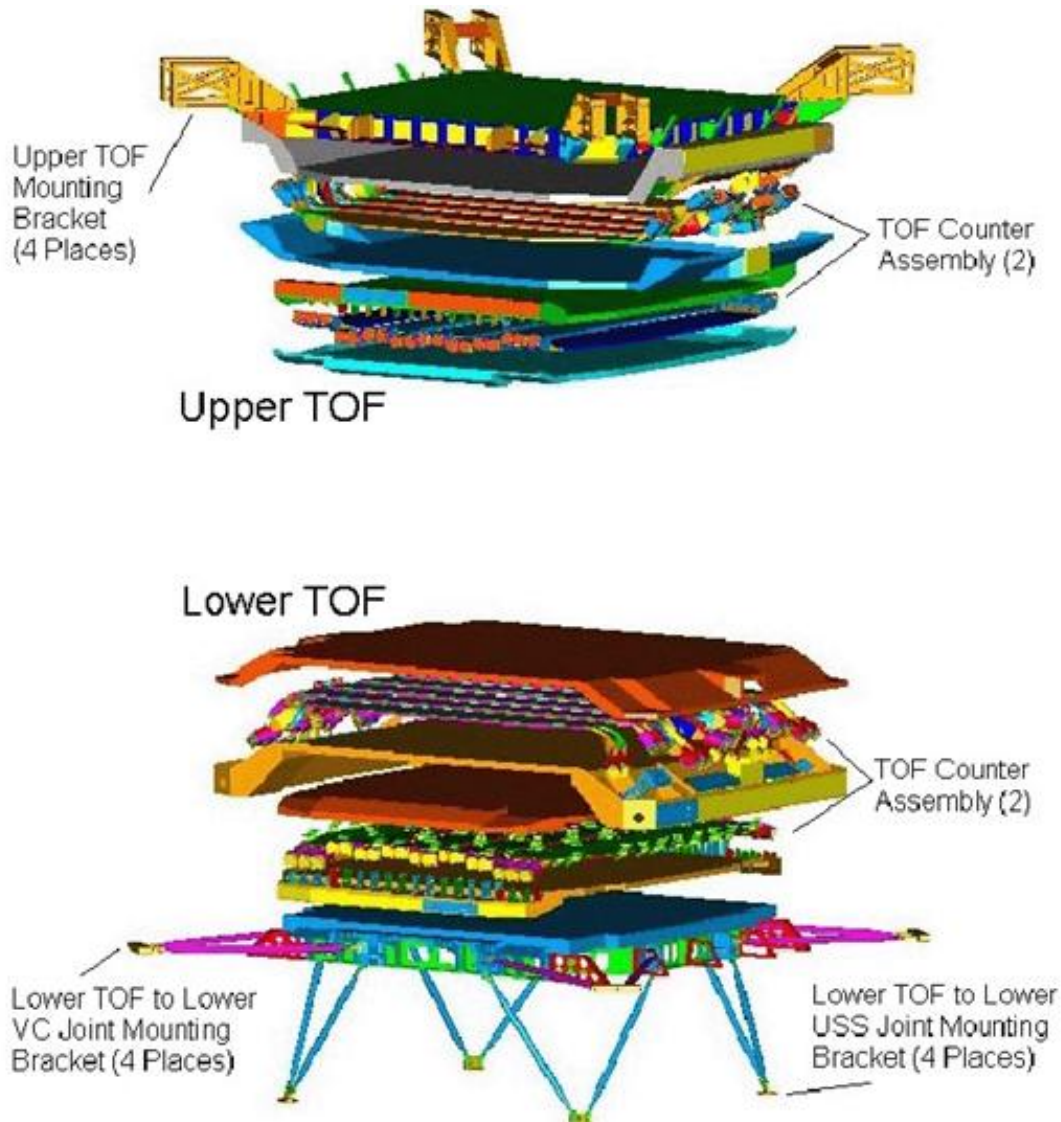


Figure 4.5-1 Time of Flight Counter Construction

4.6 Star Tracker

To accurately determine its position, AMS carries a Star Tracker called Astro Mapper for Instrument Check of Attitude (AMICA). The AMICA is equipped with a pair of small optical telescopes (AMICA Star Tracker (ASTC)). The ASTC's are mounted to the upper VC Conical Flange on opposite sides of AMS to increase the probability that one has a clear view of the stars.

The hardware consists of an f/1.25 lens with 75 mm focal length and a 6.3° X 6.3° field of view, a lens cover containing a 3 mm thick blue filter and a 2 mm thick red filter; a low noise frame-transfer Charged Coupling Device (CCD) (512 X 512 pixels); and a baffle to limit the stray light intrusion to the optics. The baffle is made of black anodized aluminum 6061 that is 1 mm thick. The baffle is not mechanically connected to the lens assembly and is supported independently by a bracket mounting the baffle to the M-Structure. This configuration allows for relative motion between the baffle and the lenses without leaking light into the optical path. The interface between the baffle and the lens assembly is made light tight by a fabric Multi-layer Insulation (MLI) cover.

4.7 Anti-Coincidence Counters (ACC)

The ACC is a single layer of scintillating panels that surround the AMS-02 Silicon Tracker inside the inner bore of the superconducting magnet. The ACC identifies particles that enter or exit the Tracker through the side. This provides a means of rejecting particles that have not passed through all the detectors and may confuse the charge determination if they leave "hits" in the Tracker close to the tracks of interest.

The ACC scintillating panels are fitted between the Tracker shell and the inner cylinder of the VC, which contains the Cryomagnet system. The ACC is composed of 16 interlocking panels fabricated from BICRON BC414 (Figure 4.7-1). The panels are 8-mm thick and are milled with tongue and groove interfaces along their vertical edges to connect adjacent panels. This provides hermetic coverage for the ACC detection function around the Silicon Tracker. The panels are supported by a 33.46" tall x .78" diameter x 0.047" thick M40J/CE Carbon Fiber Composite Support Cylinder.

4.8 Silicon Tracker

In addition, the Tracker is equipped with an infra-red (IR) laser Tracker Alignment System (TAS). It will periodically monitor the x- and y-position of the tracker layers with respect to each other. The laser beam passes through selected alignment holes in each detector plane where the beam can

penetrate but still be detected by the layer. For redundancy, the full alignment system consists of 10 pairs of beams, placed in the center of the tracker. Five pairs of beams traverses up and the other five pairs traverses down.

The AMS-02 Tracker is a modification of the Tracker that flew on AMS 01. It utilizes the same honeycomb panels and exterior cylindrical shell. The Tracker mounts at eight attach locations (four at the top, four at the bottom) to the VC conical flanges.

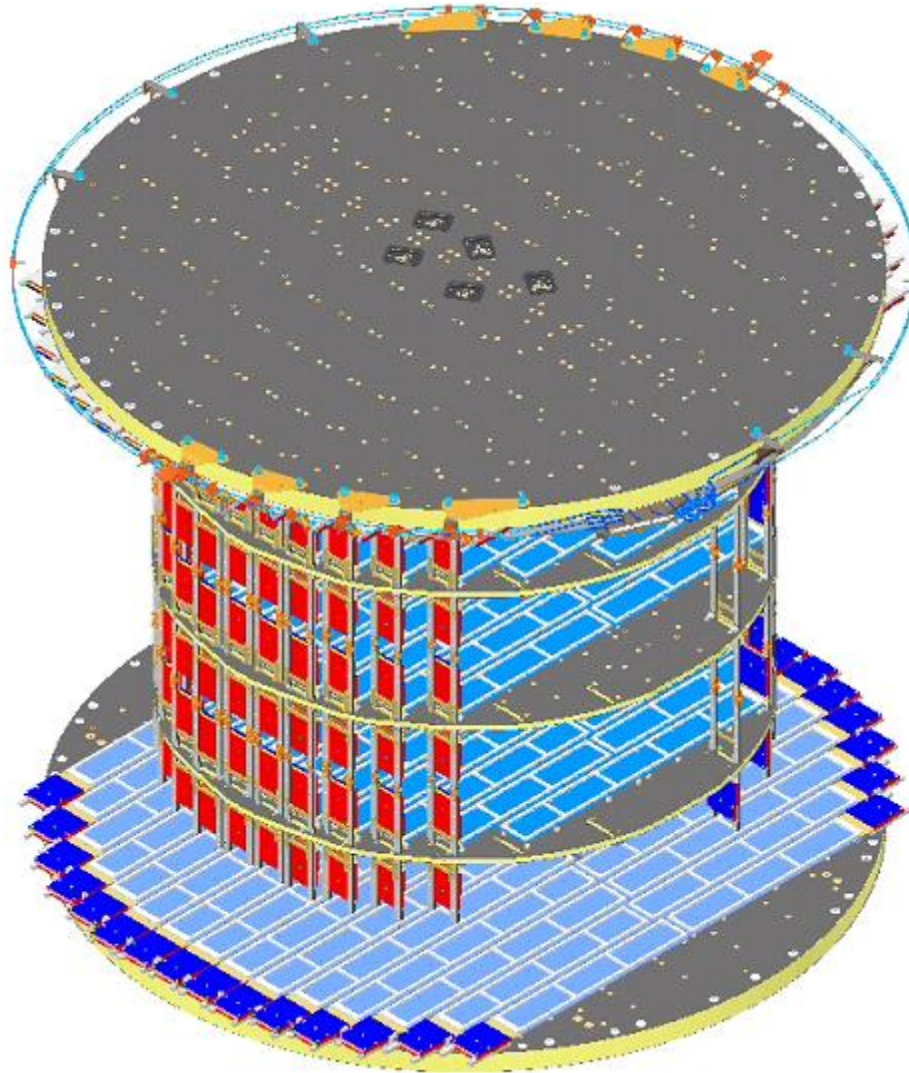


Figure 4.8-1 Silicon Tracker

4.9 Ring Imaging Cerenkov Counter (RICH)

The RICH (Figure 4.9-1) is located near the bottom of the experiment stack, below the Lower TOF and above the Electromagnetic Calorimeter (ECAL). The RICH is used in conjunction with the

Silicon Tracker to establish the mass of particles that traverse the AMS-02. Functionally, the RICH is composed of three basic elements. The top layer, the Cerenkov radiator, is composed of silica aerogel and sodium fluoride blocks that serve as sources for the Cerenkov radiation generated by the passage of the high energy particles. The intermediate layer is the conical mirror, the PMT Structural interfaces make up the third layer.

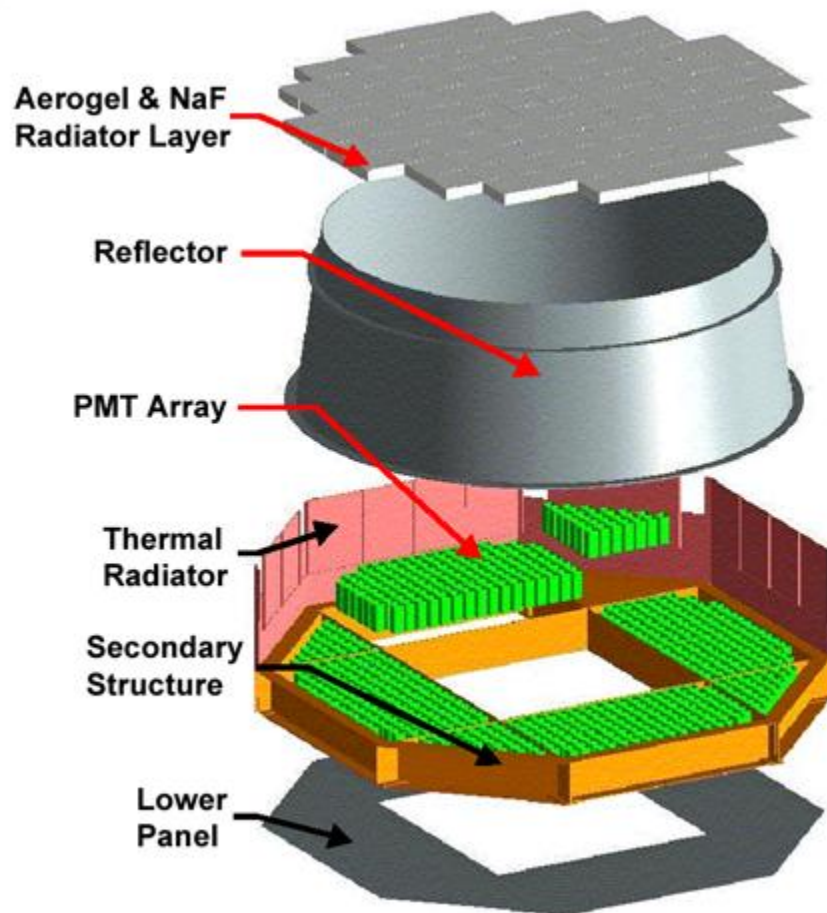


Figure 4.9-1 RICH Basic Elements

4.10 Electromagnetic Calorimeter (ECAL)

The ECAL (Figure 4.10-1) is a scintillating fiber sampling calorimeter that allows precise, 3-dimensional imaging of the shower of smaller particles generated when a particle collides with the calorimeter. The calorimeter also provides a stand-alone photon trigger capability to AMS. The ECAL measures the energy of electrons, positrons and gamma rays up to one TeV. Refer to Figure 4.10-1 for a general diagram of the ECAL.

The active sensing element of the ECAL consists of layers of lead foils and polymer scintillating fibers. Each lead foil is a lead-antimony alloy with a density of $11.2 \pm 0.5 \text{ gr/cm}^3$ with an effective thickness of 0.04". Each lead layer is grooved on both sides to accommodate the PolyHiTech Polifi 0244-100 scintillating fibers. Each fiber is 1.0 mm in diameter and is secured in the aligned grooves with BICRON BC-600 optical glue that is applied as lead layers are assembled and pressed together. Each layer consists of 490 fibers across the 25.9" width. Lead layers are grouped together in "superlayers" that are comprised of eleven layers of lead foil and ten layers of scintillating fibers. Each superlayer has all scintillating fibers oriented in the same direction while the nine superlayers alternate direction orthogonally. Once assembled and pressed, each cured superlayer is milled to a uniform thickness of 0.7". The superlayers are assembled as larger elements and milled for flight into 25.9" squares. The bottom layer of the ninth superlayer has been replaced with a milled aluminum plate to reduce the weight of the overall ECAL. The assembled ECAL is approximately 31.5" square x 9.8" high and weighs approximately 1478 lbs. Approximately 75% of this weight is the lead foils.

The superlayer assembly, or "pancake", is supported by the ECAL box. The box is made of six elements (Figure 4.10-1). The top and bottom pieces are aluminum honeycomb plates framed with aluminum. The plates are bolted to four lateral panels along the edges. The four lateral panels are made of 4" thick aluminum plate carved with a series of 1.26" square holes to house the light collection system. Four corner brackets, made of aluminum plate, link the four plates together and connect the detector to the bottom of the USS-02. The four mounting locations include a pair of radially-slotted holes to limit the loads from the USS-02 that are transferred into the ECAL.

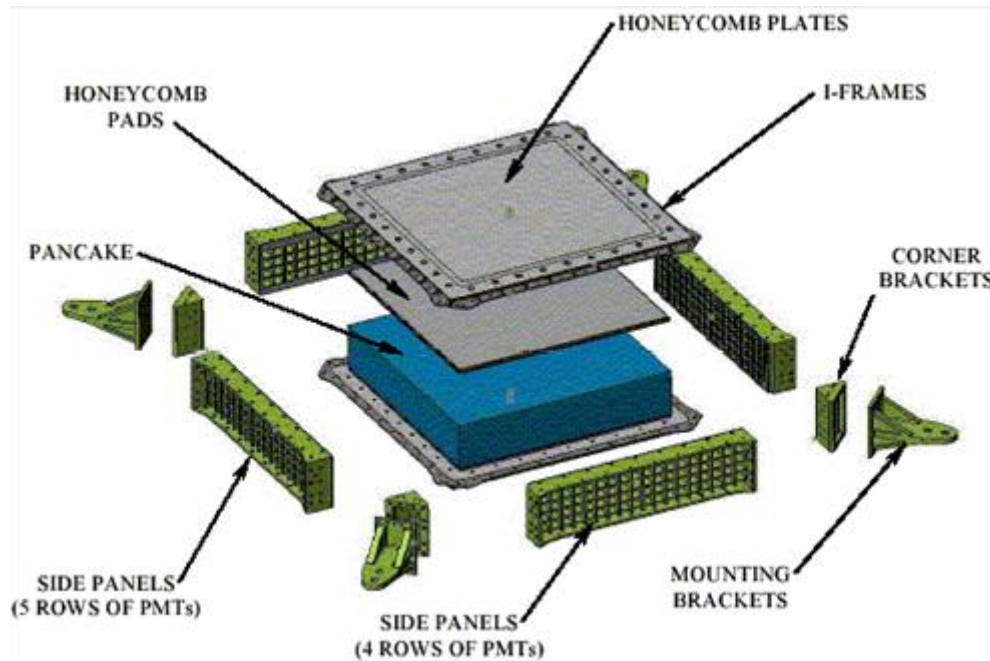


Figure 4.10-1 ECAL

4.11 Power Distribution System (PDS)

The PDS (Figure 4.11-1) consists of four distinct sections: 120 Vdc Input; 120 Vdc Output; 28 Vdc Output; and Low Voltage Control and Monitor. The PDS has two independent “channels”: side A and side B (Figure 4.11-1), which have four identical subsections. The only difference between the two channels is that side A is the only side that provides power to the Cryomagnet Avionics Box (CAB) for magnet charging. Isolation between the 120V input buses A & B is provided either within the PDS by DC-to-DC converters for the 28V outputs or with double pole relays for the 120V output to the CCEB.

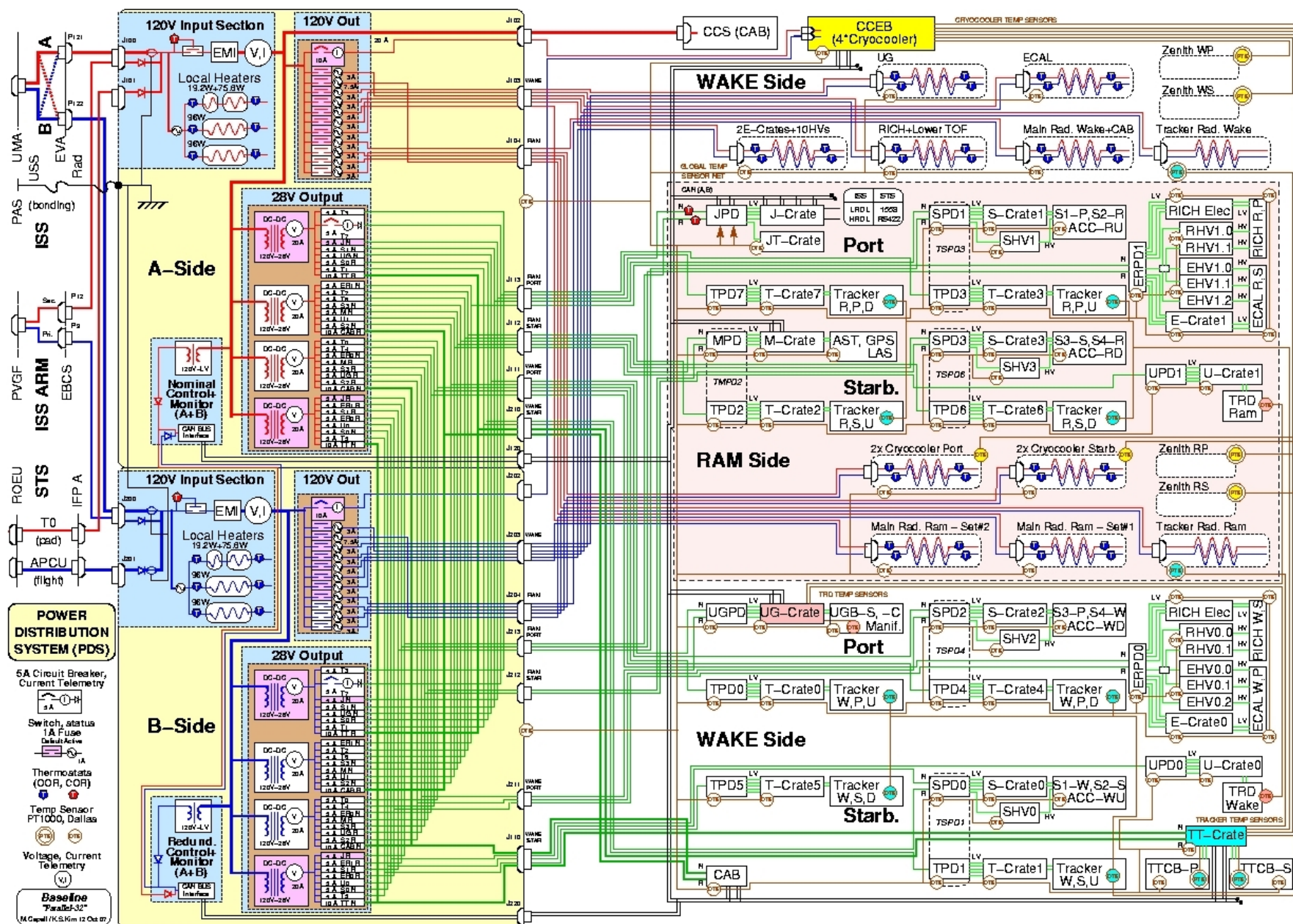


Figure 4.11-1 AMS-02 Power Distribution System, Sides A and B

4.12 High Voltage Sources

The Cryomagnet is a potential high-voltage source in the event of a quench. Other than the path to the CAB, the Cryomagnet-generated high voltage would be contained within the VC, which is grounded to the USS.

Table 4.12-1 lists the remaining high voltage and current sources on the AMS-02.

Table 4.12-1 AMS-02 High Voltage or Current Sources

High Voltages (and Currents) in AMS-02.						
Item	Subsystem	Source	Load	Voltage	Current	AWG
1	Cryocooler	CCEB	Cryocooler	<120Vpwm	<5A	3x22
2	Cryomagnet	CCS in CAB	Cryomagnet	<10VDC	<460A	3x00
3	Cryomagnet	Cryomagnet	CDD-P	<10VDC	<460A	00
4	Cryomagnet	UPS	CSP in CAB	<32VDC	<90A	3x12
5	Cryomagnet	CSP in CAB	Quench Heaters	<32VDC	<90A	3x12
6	Cryomagnet	Cryomagnet	Quench Detectors	<1000VDC	<1A	HV 24
7	ECAL	EHV	55 ECAL PMT's	<1000VDC	<250uA	HV 36
8	Interface	ISS	AMS	120VDC	<25A	8
9	Interface	ISS/PVGF	AMS	120VDC	<15A	12
10	Interface	STS/T0, APCU	AMS	120VDC	<25A	8
11	Power	PDS	CCS in CAB	120VDC	<17A	2x12
12	Power	PDS	CCEB	120VDC	<7.5A	2x12
13	RICH	RHV	40 RICH PMT's	<1000VDC	<80uA	HV 36
14	S:TOF+ACC	SHV	20 TOF+4 ACC PMT's	<2300VDC	<25uA	HV 36
15	Thermal	PDS	ECAL Heaters	120VDC	<3A	20
16	Thermal	PDS	Ram Heaters	120VDC	<7.5A	3x20
17	Thermal	PDS	TRD Heaters	120VDC	<3A	20
18	Thermal	PDS	Tracker Wake Heaters	120VDC	<3A	20
19	Thermal	PDS	Wake Heaters	120VDC	<5A	2x20
20	Thermal	PDS	LUSS Boxes	120VDC	<3A	20
21	Thermal	PDS	RICH Heaters	120VDC	<3A	20
22	Thermal	PDS	LTOF Heaters	120VDC	<3A	20
23	Thermal	PDS	CC1&2 Heaters	120VDC	<3A	20
24	Thermal	PDS	Tracker Ram Heaters	120VDC	<3A	20
25	Thermal	PDS	CC3&4 Heaters	120VDC	<3A	20

High Voltages (and Currents) in AMS-02.						
Item	Subsystem	Source	Load	Voltage	Current	AWG
26	Tracker	TPD	2 TBS in T-Crate	<120VDC	<10mA	2x22
27	Tracker	2 TBS in T-Crate	24 Tracker Ladders	<80VDC	<10mA	26
28	TRD	UPD	6 UHVG in U-Crate	<120VDC	<35mA	22
29	TRD	6 UHVG in U-Crate	2624 TRD Straw Tubes and 2 Monitor Tubes	<1800VDC	<100uA	HV 36

WIRE: AWG 00=M22759/41-02-5D, AWG 12 – 24=M22759/44-*, AWG 26=GORE PTFE ribbon Cable, HV 24= REYNOLDS 178-8066, HV-36=REYNOLDS 167-2869 coaxial

4.13 Thermal Control System (TCS)

The AMS-02 TCS has been developed and designed by the AMS experiment team. Passive thermal design options are utilized as much as possible, but more complex thermal control hardware is required for some sub-detector components to assure mission success. TCS specific hardware includes radiators, heaters, thermal blankets, heat pipes, loop heat pipes, optical coatings and a dedicated CO₂ pumped loop system for Tracker cooling. The heat pipes and loop heat pipes use ammonia that has been sealed in the pipes by the manufacturer.

4.14 Micrometeoroid and Orbital Debris (MMOD) Shielding

The MMOD shielding (Figure 4.14-1) is designed to protect the pressure systems on the AMS-02 experiment from the MMOD environments specified in SSP 30425, Paragraph 8.0. These systems include the Main Helium Tank, Warm Helium Supply, and the TRD Gas Supply. The MMOD shielding for TRD consists of two shields mounted to the upper USS-02. Each shield consists of 0.1” outer and inner aluminum sheets with a layer of 0.1” Kevlar/Nextel. Standoffs will be used to separate the outer aluminum sheet from the inner aluminum sheet. The proposed shield design is shown in Figure 4.14-1. Both sets of MMOD shields will have the same general design. The Warm Helium Tank will be surrounded by a 1” thick box of metallic foam. The VC itself provides sufficient protection for the Main Helium Tank.

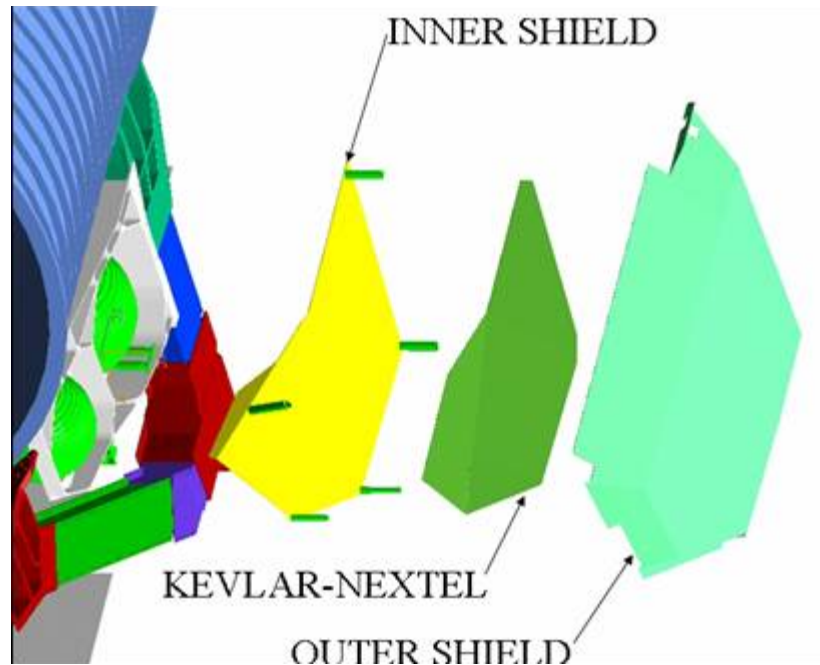


Figure 4.14-1 Proposed MMOD Shield Design

4.15 Global Positioning System (GPS)

The AMS-02 utilizes an ALCATEL TOPSTAR 3000D which will be integrated into AMS by IN2P3-Montpellier. A single Sextant Avionique model 3407-79 will be mounted on the TRD M-Structure. A signal from the GPS unit is used for precision time correlation with other experiments in the investigation of astrophysical phenomena.

5 GROUND SUPPORT EQUIPMENT (GSE) SUBSYSTEMS

Section five will describe the ground support equipment for AMS-02. There is also a list of equipment at the end of the section that the AMS-02 project is requesting from KSC.

5.1 Cryogenic Ground Support Equipment (CGSE)

The CGSE is used to prepare AMS-02 for cryogenic operations (pre-cooling), fill the Superfluid Helium Tank with liquid helium, cool the liquid helium to superfluid helium temperatures and keep the fluid tank in that state. The integrated CGSE has a number of subsystems. Some of these systems will only be used for contingency operations because the AMS-02 will arrive with some quantity of cryogenic helium in place—that is, it will arrive “cold” and should not need to be taken

from ambient temperature to its operating temperatures. These subsystems and elements of the CGSE include:

- 300-80 K System
- Liquid Helium (LHe) Transfer Dewar
- LHe Master Dewar
- Liquid Valve Box
- Gas Valve Box
- Vacuum Pump System
- Turbomolecular Vacuum Pump
- Gaseous Helium (GHe) for Superfluid Cooling Loop (SFCL)
- Pilot Valve Vacuum Vessel (PVVV) Vacuum Pump
- VH1 Heat Exchanger
- Flight Helium Tank Fill Bayonet and Lines
- Pneumatic System
- CGSE Electrical System
- Helium Leak Detector

The proposed layout of the CGSE in the SSPF and Launch Pad 1, as well as a schematic, are found in Figures 5.1-1—5.1-3.

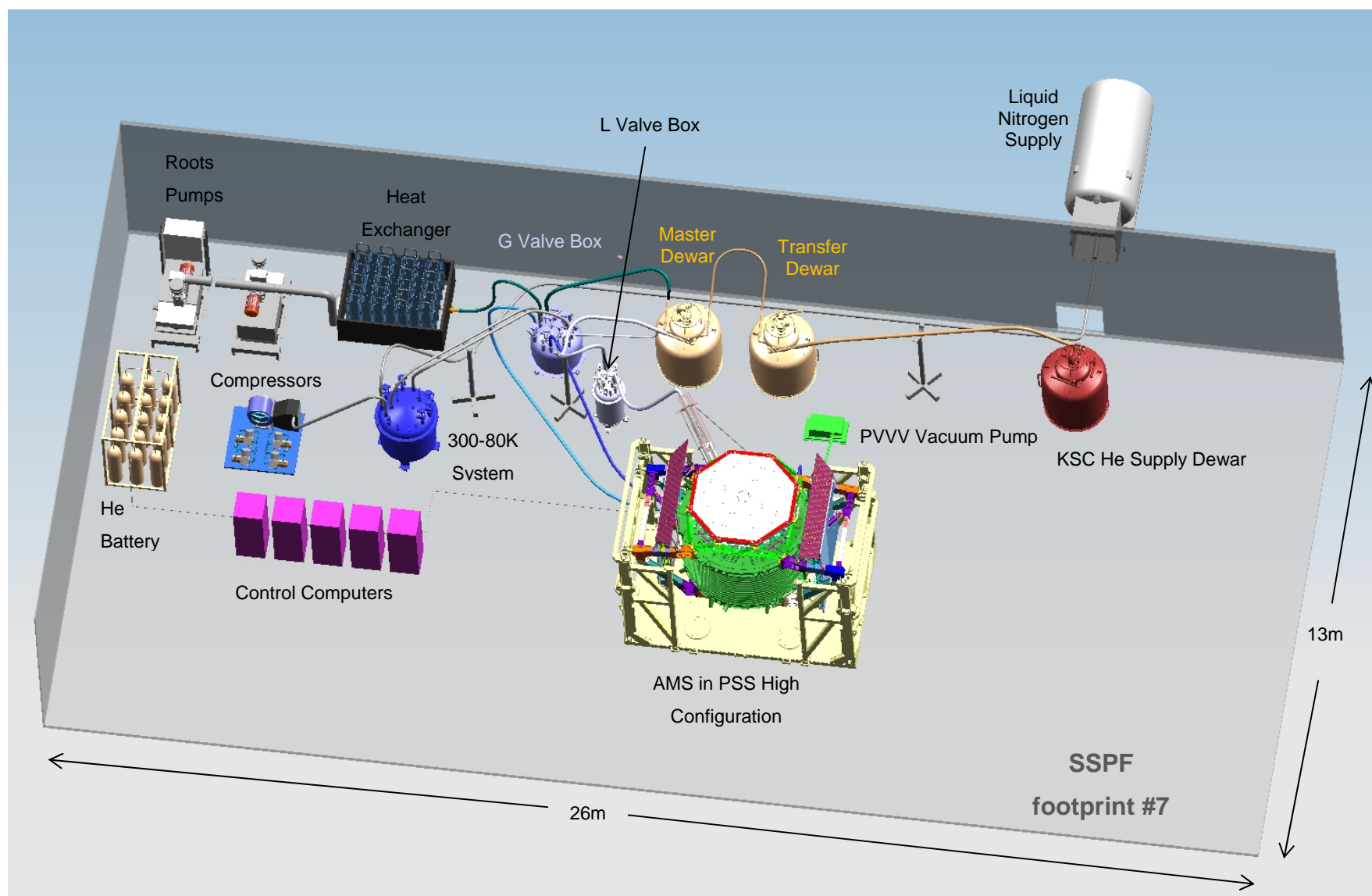


Figure 5.1-1 Proposed Layout of AMS-02 and CGSE Hardware in the SSPF

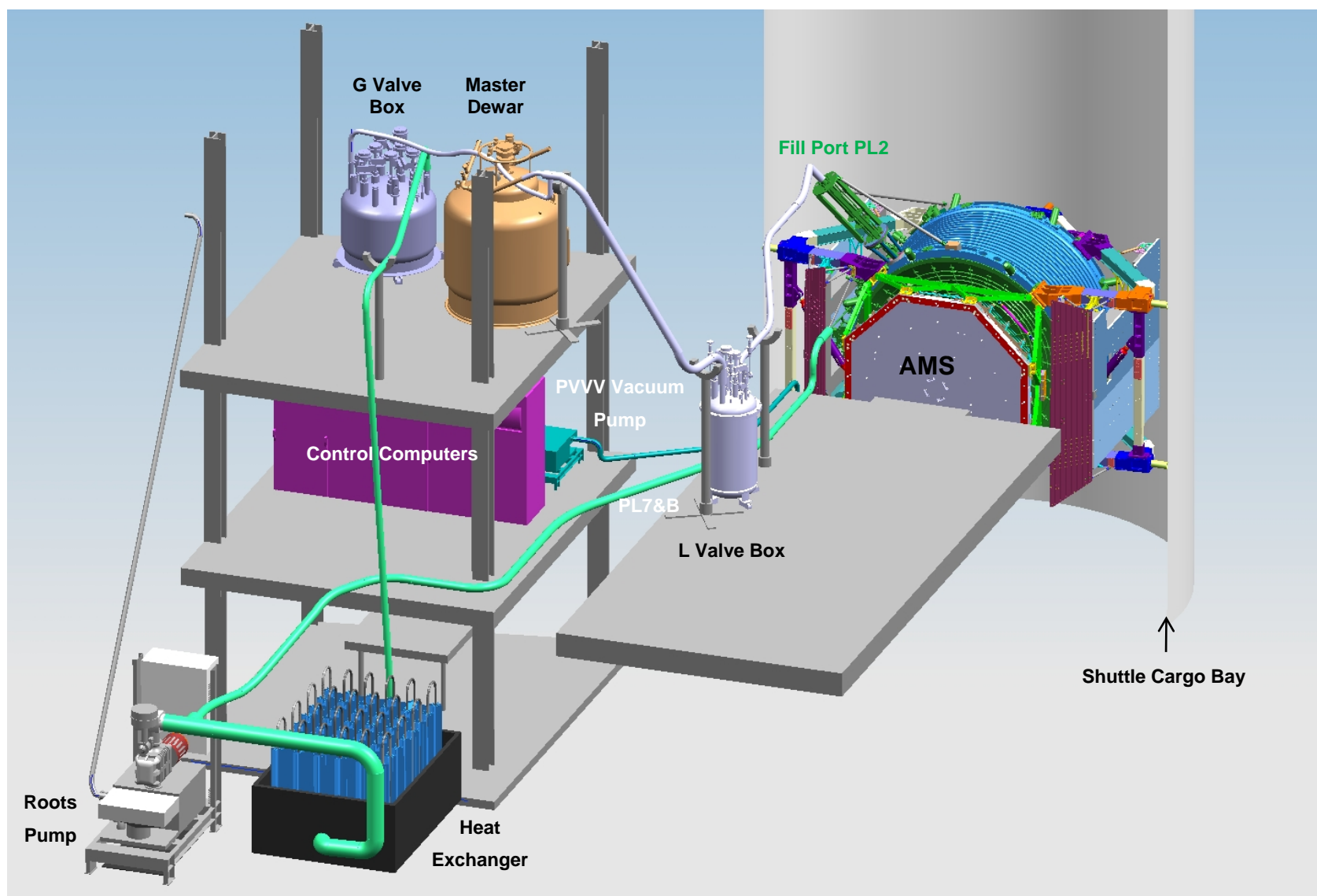


Figure 5.1-2 Proposed CGSE Layout at Launch Pad 1

5.1.1 300-80 K System

The CGSE is capable of taking the room temperature “cold mass” of the AMS-02 (magnet and cryogenic system) from ambient temperatures (300 K) to the nominal operating temperature of 1.8 K. The System 300-80K system takes the payload to approximately 80 K to prepare it for filling the main tank.

The 300-80 K system makes use of a facility-supplied liquid nitrogen source to chill pure helium gas through a series of heat exchangers to approximately 80 K. It utilizes two heat exchangers to smooth the temperature profile of circulated helium gas to allow a consistent decrease in the temperature of the flight system. A third heat exchanger utilizes a nitrogen bath to provide the overall chilling of the working fluid. It is not anticipated that this system will be required to operate at KSC because the AMS-02 will arrive cold, but it will be present in case it is needed.

The main components of the 300-80 K system are the Cryostat, Compressor System, and Heat Exchanger HX2 with an air cooling fan, and warm helium gas supply. A schematic and a picture of the 300-80 K system with the compressor system are found in figures 5.1.1-1 and 5.1.1-2.

5.1.1.1 Cryostat

The Cryostat is a vacuum shrouded vessel used for cooling down the direct helium flow. It contains the heat exchanger HX1, and the liquid nitrogen bath HX3. Both are contained within the vacuum provided by the Cryostat. Electro-pneumatic valves manufactured by Weka are used to control the helium flow and manage the flow temperature. Temperature and pressure are monitored within the Cryostat and the system is protected by burst disks, regulators and relief valves to preclude over-pressurizing the components or plumbing. It is not anticipated that this system will be required to operate at KSC because the AMS-02 will arrive cold, but it will be present in case it is needed.

The Cryostat is made of stainless steel 316L and mounted on lockable casters. It can be moved by one person and is designed to be hoisted. The Cryostat is 2.2 m in height and 1.36 m in outer diameter at the flange. It weighs 560 kg empty and can contain 132 L of liquid nitrogen. It is manufactured by Lanzhou Vacuum Equipment Co., Ltd.

5.1.1.2 Compressor System

The compressor system consists of four 1kW KNF diaphragm pumps working in parallel. It is capable of providing up to 2 g/sec helium gas. This is accomplished by switching on/off one, two,

three or four of the pumps. Each pump weighs 30 kg. Over-pressure from the valves is precluded by overflow valve CVR3 (2.1 bar) and valve CVP7 when commanded through the output of CP1 sensor readings. Burst disk CBD1 ultimately limits the pressure to 3 bar.

5.1.1.3 Heat Exchanger HX2

Heat Exchanger HX2 is used as the first stage for helium flow cooling and for the warm up of both helium back flow and nitrogen vapors to room temperature. Ambient air flow produced by the fan is used for cooling down direct flow and warm up back flows. The HX2 is 1.10 m x .66 m x .70 m. The fan requires 6 kW of electrical power.

5.1.1.4 Warm Helium Gas Supply

The warm helium supply is a rack of twenty-four, 40 liter tanks filled to 200 bar, each with grade M-P-27407A purity helium or better. Pressure regulators provide the gas to the compressor system at 0.05 bar. KSC will provide the helium tanks or equivalent for AMS-02 operations at KSC if the 300-80 K system is used.

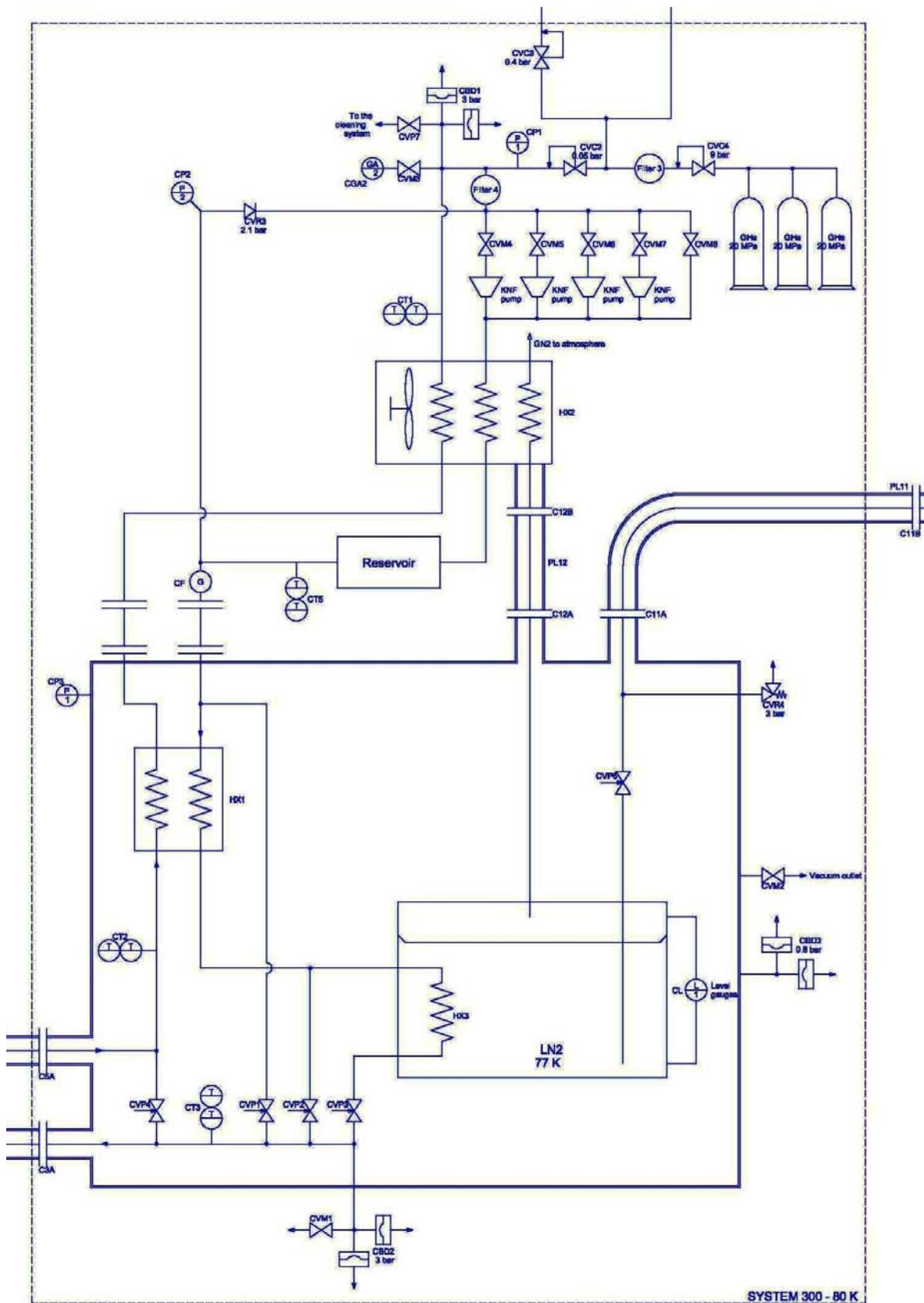


Figure 5.1.1-1 System 300 – 80 K Flow Diagram



Figure 5.1.1-2 300-80K System

5.1.2 LHe Transfer Dewar/ LHe Master Dewar

The Transfer and Master dewars are of identical design. Both are produced by Wessington Cryogenics in England. LHe dewars are high performance storage and transfer devices, capable of holding and delivering 1000 liters of liquid helium in either normal (4.2 K, 1 atmosphere) or near-superfluid (2.3 K, 53 mbar) conditions. Each one weighs 900 kg and is 1.5 m x 1.5 m x 2 m. Each is on lockable casters, is movable by one person, and is capable of being hoisted with permanently attached lifting points. All required pressure gauges, pumping ports, and pressure relief devices are mounted on the dewars. A schematic of the dewar set-up and a picture of one of the dewars are found in figures 5.1.2-1 and 5.1.2-2, respectively.

The LHe dewars are designed to guarantee leak tightness and eliminate any possibility of air leakage into the system. Burst disks are used instead of relief valves since the latter cannot guarantee tightness when the internal pressure is sub-atmospheric. Pressure relief consists of a 1 bar (14.5 psig) burst disk and 0.6 bar (10 psig) relief valve on the vent line. The line with the 0.6

bar (10 psig) relief valve can be closed off during pumping of the LHe Dewar to avoid risk of air leakage inside the system. During operations with slightly pressurized helium (fill and storage operations with normal liquid helium) the line is open to allow the tank pressure to rise to 0.6 bar (10 psig). The outer shell has a relief pump-out port set to less than 0.34 bar (5 psig). The MDP of the inner tank is 4.14 bar (60 psig). It is designed to handle a maximum of 16.5 bar (240 psig) and the outer shell a maximum of 2.1 bar (30 psig). The inner tank has been tested to 6.72 bar (97.5 psig).

Both dewars will be used in the Space Station Processing Facility (SSPF). Only the Master Dewar will be used in the Payload Changeout Room (PCR). Both require pressurized helium for flow. The helium bottles are supplied by KSC. The line and regulator are supplied by the project. KSC will also provide LHe grade M-P-27407A purity or better to fill the LHe dewars while at KSC.

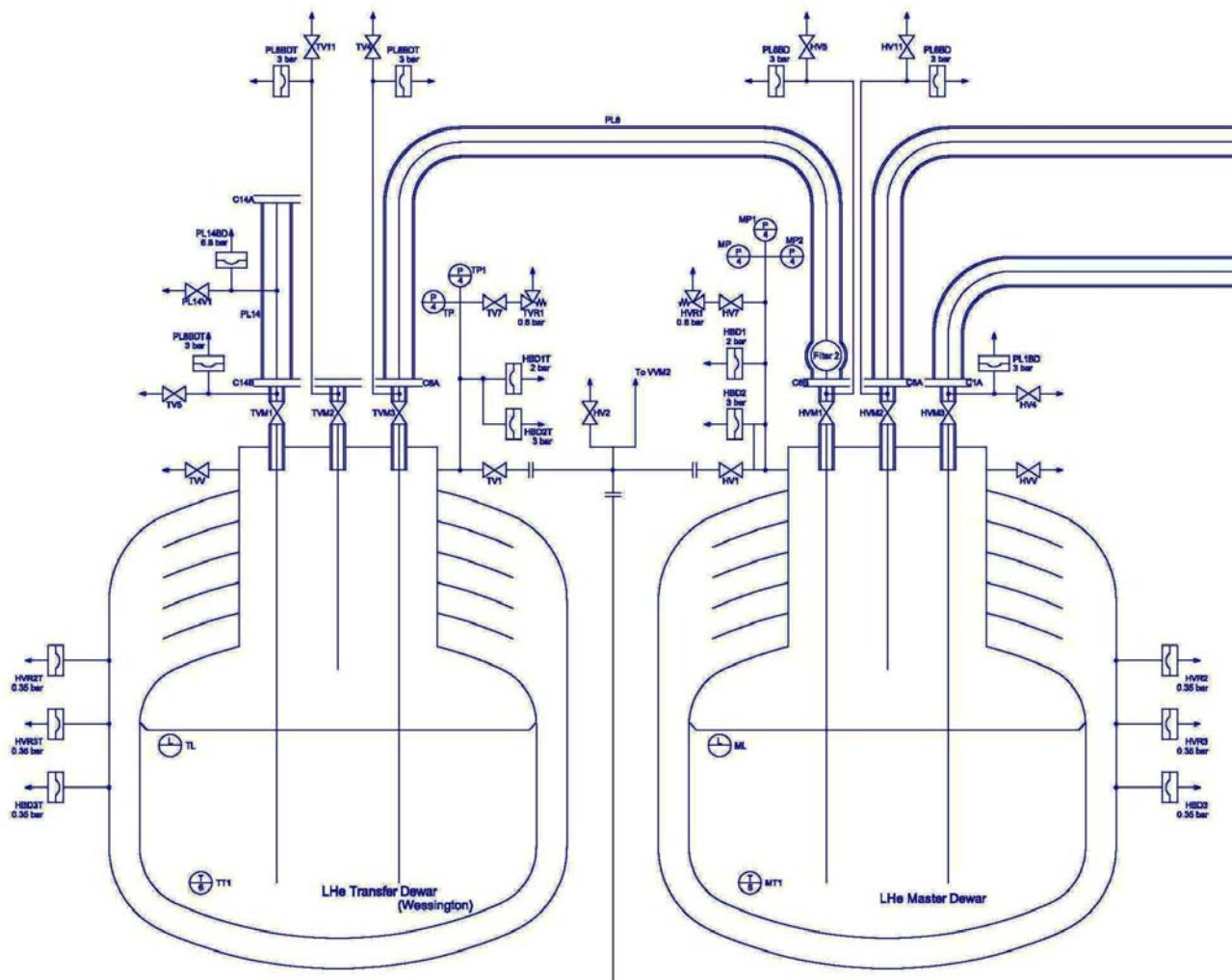


Figure 5.1.2-1 Master and Transfer Dewar Flow Diagram



Figure 5.1.2-2 CGSE Dewar (From Wessington, England)

5.1.3 Liquid (L) and Gas (G) Valve Boxes

The L and G valve boxes are used for providing vacuum insulation for the CGSE cryogenic valves, filtering solid particles from the LHe, and operating the CGSE in all modes. A schematic of the L

and G Boxes can be found in Figure 5.1.3-1. Pictures of the L valve box and the G valve box are found in figures 5.1.3-2 and 5.1.3-3, respectively. Both boxes were manufactured by Lanzhou Vacuum Company.

The L Valve Box comprises of Filter 1; valves VVM1, VVM3, VVM4, VVM5, VVM6, VVM7, VVP5, VVP9, and VGA1; pressure sensors VP1 and VP3; temperature sensors VT1, VT2, and VT4; burst disks VBD2, VBD5, VBD8, VBD9 and VBD10; and cold bayonets C1B and C2B.

During AMS-02 filling, LHe from the Master Dewar enters the L valve Box via cold bayonet C1B, passes valve VVM1, and enters Filter 1 where solid particles are trapped. Sensor VT2 controls LHe temperature. Then the LHe passes J-T valve VVP9 which creates the required pressure difference between normal liquid helium (4.2 K, 1 atm) and superfluid helium (1.8 K, 16 mbar). Then, via cold bayonet, C2B superfluid helium goes to the line PL2 connected to AMS-02.

LHe flow can by-pass AMS-02 during Liquid Valve Box cool down via valve VVP5 if necessary. Back flow of cold helium from the payload pumped through the vapor-cooled shield of the Liquid Valve Box provides additional cooling. Sensors VT1 and VP1 measure the state of the helium back flow.

Should Filter 1 become blocked by frozen particles of trace gases, it can be cleared. Filter 1 is isolated from the remainder of the system by valves VVM1, VVP5, and VVP9. It can then be warmed up by room temperature gaseous helium via valves VVM3 and VVM4. Valve VVM6 can be used to by-pass the blockage and warm up the filter. Sensor VT4 measures the temperature of the filter. Sensor VP3 measures pressure difference on the filter and allows troubleshooting of filter problems.

In case LHe is trapped in the lines, there are 7 bar burst disks to prevent them from over-pressurizing: VBD2 protects the filter, VBD5 protects line PL1, and VBD9 and VBD10 protect line PL2. Over-pressurization of the Liquid Valve Box casing is prevented by the 0.8 bar burst disk VBD8.

The Liquid Valve Box is on lockable casters, is movable by one person, and is capable of being hoisted with permanently attached lifting points. Overall dimensions of the Liquid Valve Box are 1.95 m x .750 m including castors. It weighs 530 kg and is manufactured by Lanzhou Vacuum Company. It is used in both the SSPF and PCR.

The Gas Valve Box is used to collect all gaseous helium flowing from AMS and to provide a flow of gaseous helium that cools the 300- 80 K system. It is comprised of valves VVP1, VVP2, VVP3, VVP6, VVP7, CGA1, CVC1, CVP5, and VVM8; relief valve VVR3; valve cold bayonets C3B, C4B, C5B, C6B, C7B, C9B, C10B, and C13B; temperature sensor VT5; pressure sensor VP2; and burst disks VBD1, VBD3, VBD6, and VBD7.

Valves CVC1 and CVP5 are opened only in the “300-80 K” mode and provide a connection to the 300-80K system. Valve VVP3 controls helium backflow from the AMS Cool Down Circuit (CDC). Valve VVP6 controls helium backflow from the AMS VCS. VVP7 is used to control the flow of helium vapor from the LHe Master Dewar. Valves VVP1 and VVP2 remove helium vapor from AMS in the 80-4.2 K mode and 4.2-1.8 K mode, respectively. Both are closed in the “300-80 K” mode. VVM8 allows vacuum pumping of the case. Relief valve VVR3 prevents line PL7 and the payload from over-pressurization.

The Gas Valve Box is on lockable casters, is movable by one person, and is capable of being hoisted with permanently attached lifting points. Overall dimensions of the Gas Valve Box are 1.50 m x 1.265 m including castors and weighs 967 kg. It is manufactured by Lanzhou Vacuum Company. It is used in both the SSPF and the PCR.

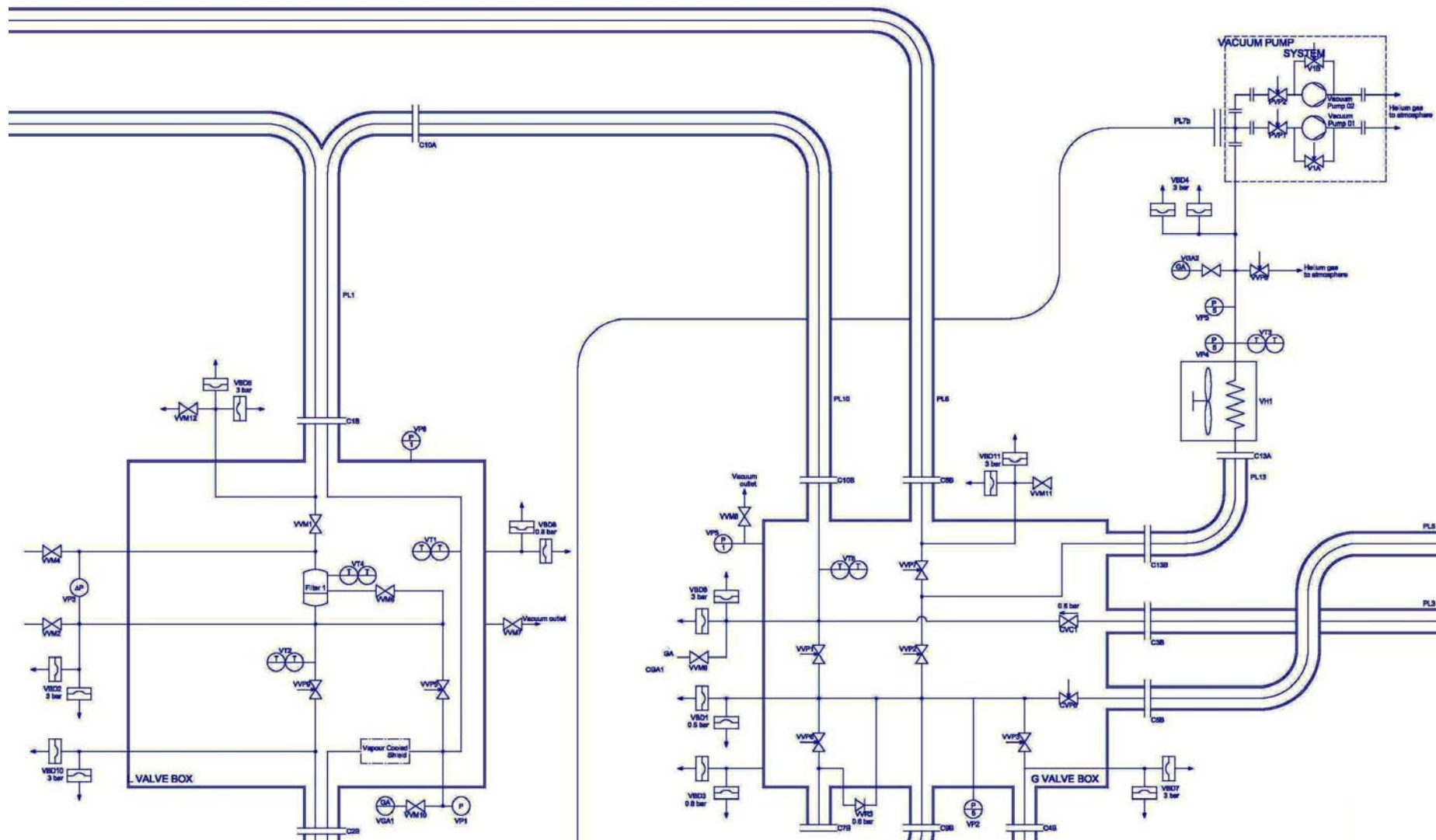


Figure 5.1.3-1 Gas and Liquid Box Flow Diagram



Figure 5.1.3-2 Liquid Valve Box



Figure 5.1.3-3 Gas Valve Box

5.1.4 Vacuum Pump System

The Superfluid Vacuum Pump System is used to lower the vapor pressure of liquid helium in both the CGSE master dewar and flight magnet dewar, thereby lowering the temperature of the liquid helium and converting it to the superfluid state. Two Leybold RUTA WS2001FU/SV630F/A vacuum pumps are connected in parallel for redundancy while AMS is at the SSPF. In the PCR, only one vacuum pump will be used to draw a vacuum on the dewars. The system regulates the throughput of each pump from 0 to 2000 m³/h. The power requirements for this system are 400V, 50 Hz /460V, 60 Hz. The dimensions of each of the two pumps are 1 m x 2 m x 2 m. Each pump weighs 1200 kg. A picture of the two pumps is found in figure 5.1.4-1.

5.1.4.1 On-Board Pump

A smaller vacuum pump is located on the payload itself, and will be used for pre-launch activities to vent the Helium tank vapor pressure after the payload bay doors are closed and prior to lift-off. The pump is discussed in this document, even though considered “flight” because of its implications in ground use and necessary GSE. A remotely controlled and monitored GSE 110 VAC power supply will power this pump for pre-launch pad operations. These operations may also include payload canister transportation.



Figure 5.1.4.1-1 Leybold Vacuum Pumps

5.1.5 Turbomolecular Vacuum Pump

The Turbomolecular Vacuum Pump will be used to pump down CGSE vacuum spaces. It will be used at the SSPF during payload testing. The lines and regulators are provided by the project. It has a 230 V, 50/60 Hz power requirement. The pump is manufactured by Pfeiffer.

5.1.6 Gaseous Helium (GHe) for Superfluid Cooling Loop (SFCL)

This system is used for filling the AMS-02 SFCL with liquid He. It consists of the following components:

- Warm helium supply - cylinders with pressurized gaseous He (seven standard 40 l, 200 bar cylinders)
- Pressure reducer which limits output pressure to no more than 1 bar
- Oscillation damper (designated LOD)
- Pressure sensor (designated LP) and gas analysis output sensor (designated LGA)
- Output to the cleaning system
- A pressure relief valve (designated LVP) which releases He in case of overpressure during the warm up cycle. It does this when it receives a signal from sensor LP.
- Seven bar burst disks for safety

The system is used to fill the AMS SFCL with superfluid helium (SFHe) by liquefying gaseous He during cool down of the SFCL. A schematic and picture of the system are found in figures 5.1.6-1 and 5.1.6-2, respectively.

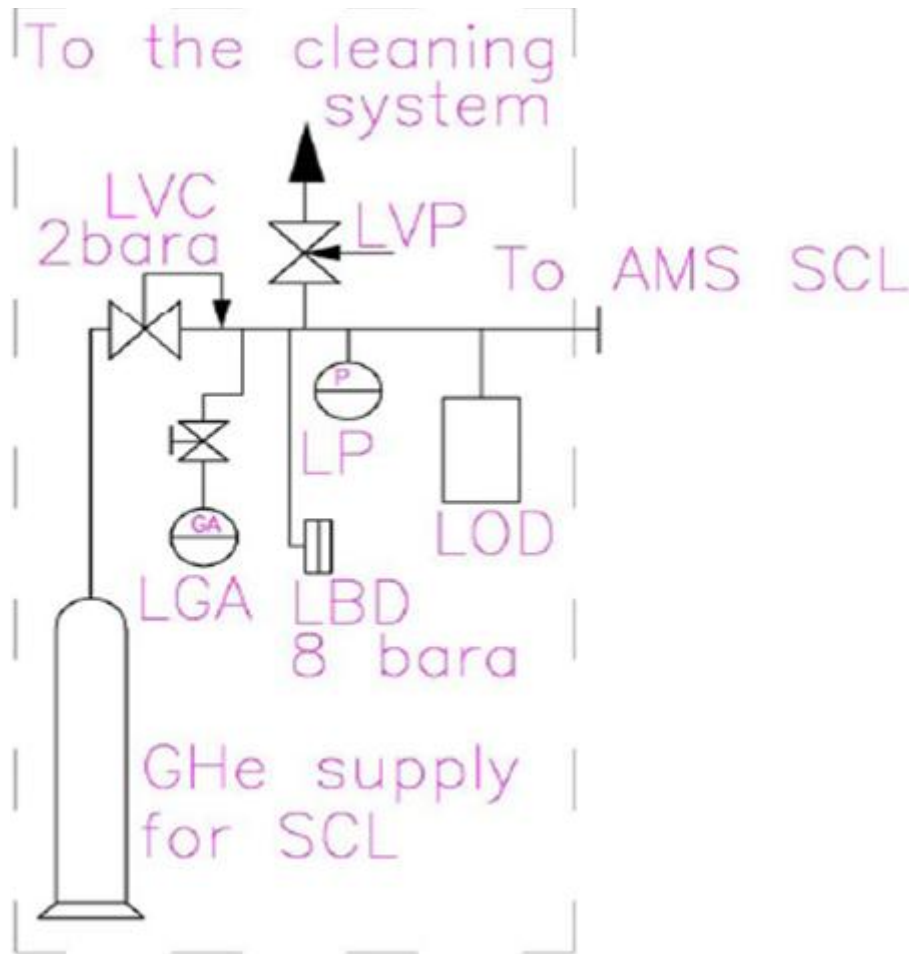


Figure 5.1.6-1 Flow Diagram for GHe Supply System for AMS-02 SFCL



Figure 5.1.6-2 GHe Supply System for AMS-02 SFCL

5.1.7 Pilot Valve Vacuum Vessel (PVVV) Pump

The PVVV pump is used to create a vacuum in the PVVV, which is part of the AMS-02 flight hardware. It is an Edwards XDS5 Scroll vacuum pump with overall dimensions of .4 m x .25 m x .3 m and a weight of 30 kg. It has a power requirement of 220 V, 50 Hz.

5.1.8 VH1 Heat Exchanger

Heater-fan VH1 is used to warm up cold helium vapor back flow to room temperature before it enters the vacuum pump system or is released into the atmosphere. The input He temperature is anywhere from 1.8-80 K and the output temperature has a range of 278-300K. The nominal flow pressure is between .01 to 1.2 bar absolute. The exchanger's MDP is 16 bar gauge. Its overall dimensions are 2 m x 1 m x 1.8 m and weighs 300 kg. The VH1 has wheels so that it can be rolled

along the floor (the wheels are lockable). It also has permanently welded lifting points that have been designed with a safety factor no less than four. A picture of the VH1 is found in figure 5.1.8-1.



Figure 5.1.8-1 VH1 Heat Exchanger

5.1.9 Flight Helium Tank Fill Bayonet and Lines

The LHe fill lines PL1 and PL2 connect the LHe Master Dewar and Gas and Liquid Valve Boxes to the AMS-02 helium tank. Lines PL14 and PL8 are used to fill the CGSE dewars. PL14 and PL8 have fine filters for providing high grade LHe filtration. Lines PL1 and PL2 have an inner pipe for LHe filling and shrouds cooled by helium back flow to reduce heat leakage into the LHe. Burst disks are installed at the ports to which these lines are connected to relieve pressure in case helium is trapped between valves. The Maximum Dynamic Pressure (MDP) of the lines is 4.5 bar (65.3 psig). Maximum working pressure is 0.6 bar and is limited by the maximum pressure in the LHe dewar. The burst pressure is 18 bar (261.1 psig). The cryogenic lines were made by the Chengdu Holy company.

Line PL2 connects the Liquid Valve Box with the AMS LHe fill port. At the end of this line there is a LHe fill port insertion device, the tank fill bayonet, which is used to connect the line with the AMS LHe fill port.

Other cryogenic lines are used to provide gas helium circulation between CGSE and AMS. Lines that will be used in the PCR include PL1, PL2, PL6, PL7, PL10 and PL13.

A schematic and picture of the bayonet are found in figures 5.1.9-1 and 5.1.9-2, respectively.

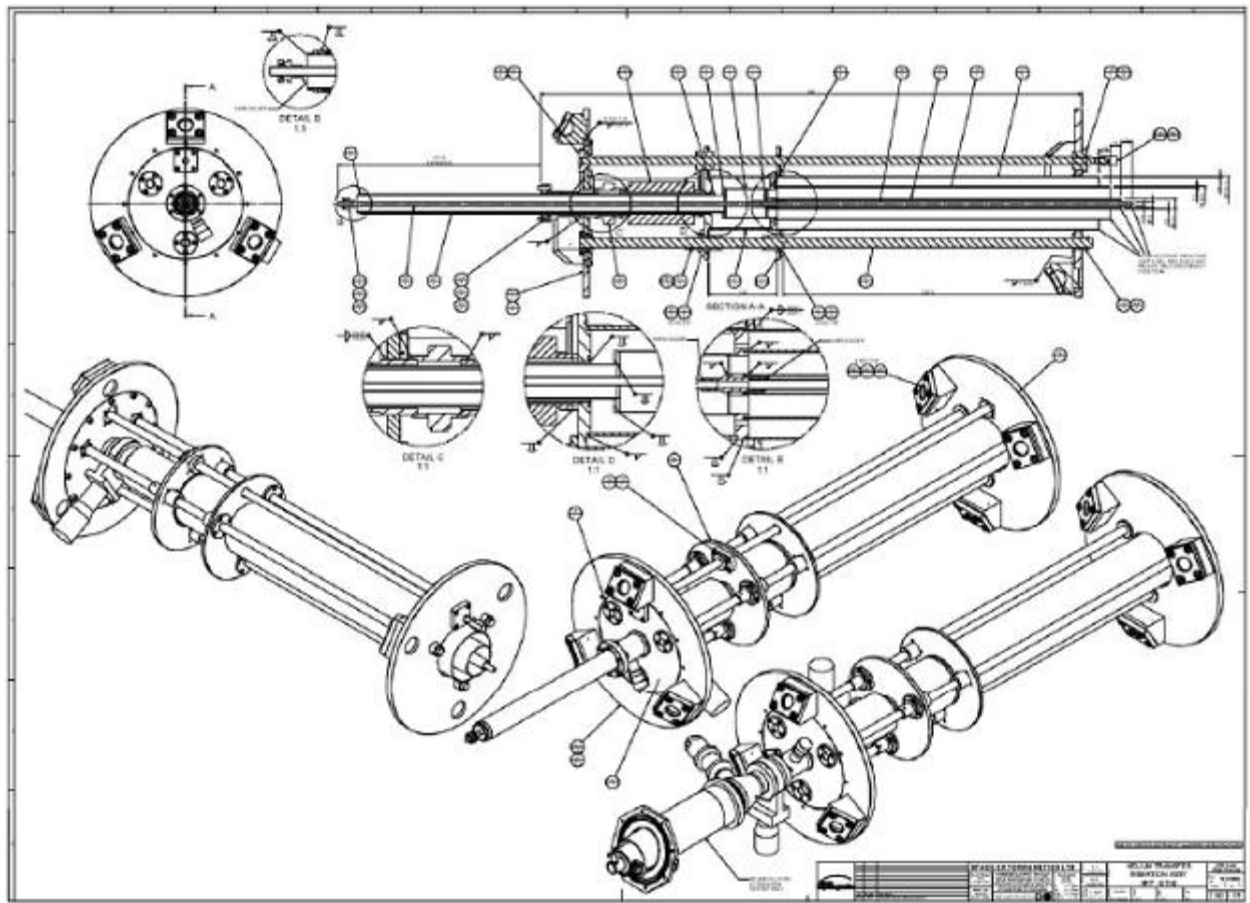


Figure 5.1.9-1 PL1 Insertion Device that Connects to AMS-02 Fill Port



Figure 5.1.9-2 Insertion Device Connected to AMS-02 Simulator

5.1.10 Pneumatic system

The pneumatic system is used to control the CGSE pneumatic valves. It consists of pneumatic pipes which distribute the pressurized air between the Weka pneumatic valves. The system can be connected to a central pneumatic air system if available. The system will use SSPF shop air.

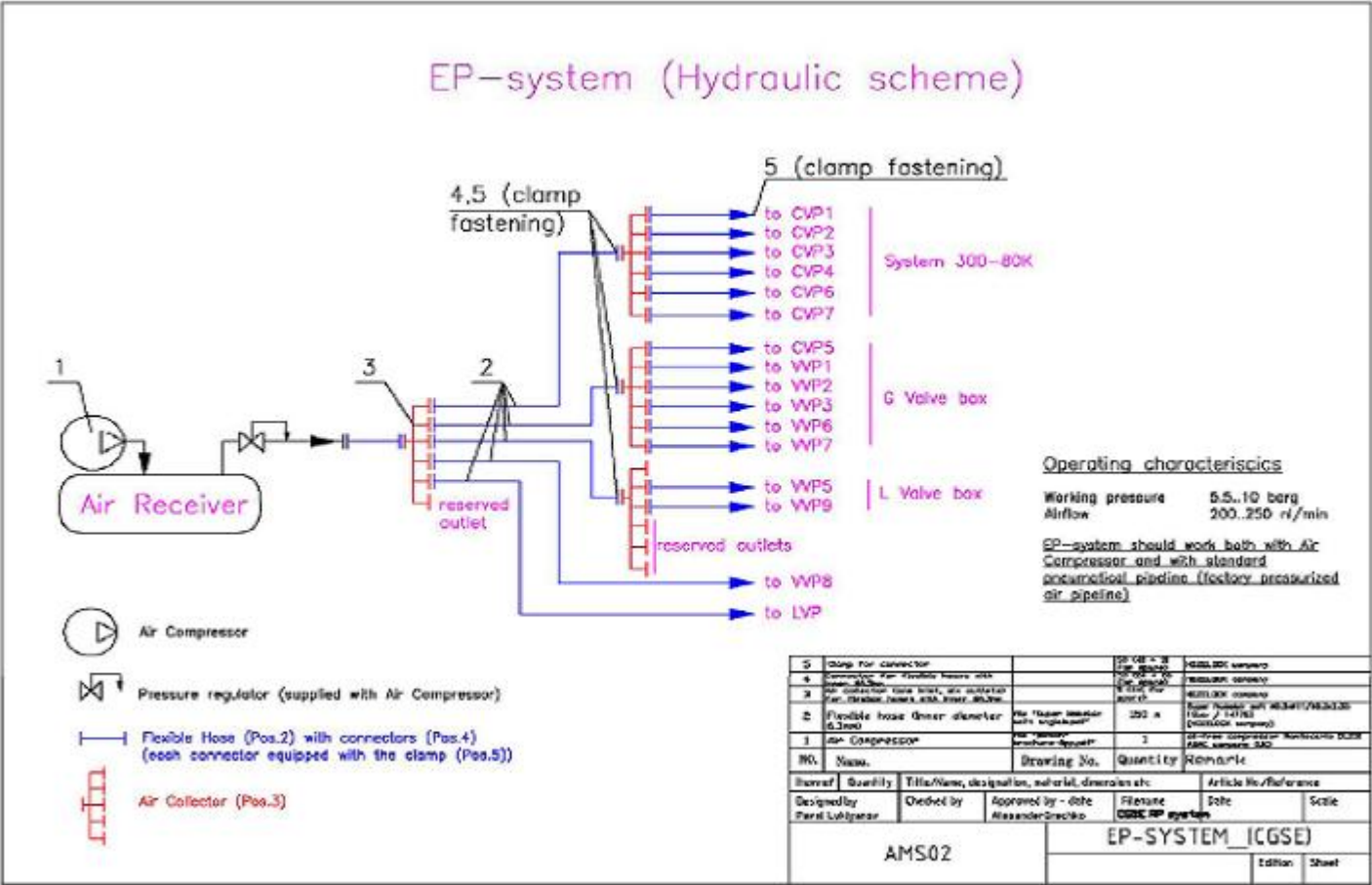


Figure 5.1.10-1 Pneumatic System Diagram

5.1.11 Support Stands for CGSE Cryogenic and Vent Lines

In order to prevent loading on AMS-02 flanges, support stands will be used to support the CGSE cryogenic and support lines. There are 35 stands that are adjustable between 1.6 and 2.5 m. Their maximum load capacity is 150 kg. A schematic of a typical support stand is found in figure 5.1.12-1.

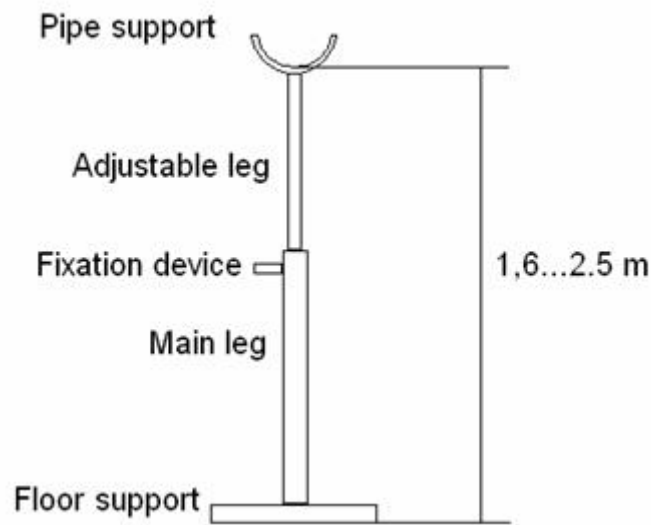


Figure 5.1.11-1 Cryogenic and Vent Line Support Stand

5.1.12 CGSE Electrical System

The CGSE Electrical System (CGSE-ES, Figure 5.1.12-1—5.1.12-2) consists of a Siemens Programmable Logic Controller (PLC) and six computers (two of which are redundant). Computers 1A and 1B provide redundant measuring and control of the CGSE Mechanical System (CGSE-MS). Computers 3 (Controller Area Network (CAN) Slave) and 4 (CAN Master) are connected to the AMS CAN Bus and provide data exchange between AMS and the CGSE control systems during tests (not in the PCR). PC Computer 8 and 10 will connect to the Ethernet and provide data exchange between AMS and CGSE control systems at the launch pad.

The CGSE-MS is interfaced to the CGSE-ES by a direct connection to the PLC. The operator interface is provided by the redundant computers 1A and 1B. The operator interface is also a graphical user interface (GUI) which displays monitoring data from and formats control commands to the CGSE-MS. Computers 1A and 1B are also used as a web server which allow any networked computers connected to CGSE- Ethernet (Computers 8 and 11), both locally and remotely, to access the CGSE operator interface in computers 1A and 1B. When the CGSE is operating during tests of AMS-02, computers 3 and 4 are used as a communication interface. They are connected to the AMS CAN bus using the EPP-CAN box. Computer three is used as a CAN-bus slave and connects to computers 1A and B, which allows any CAN-bus master (computers six and seven), both locally and remotely, to access the CGSE operator interface in one (1A and 1B). Computer four is used as a CAN-bus master, which allows CGSE-ES access to the CAB, if necessary. Any networked

computers connected to Ethernet (9 and 11), both locally and remotely, can access the CGSE Operator Interface in one (1A and 1B). When the CGSE is on the launch pad, computer one (1A and 1B) is connected to the J-crate Main Data Computers (JMDC) via KSC-Ethernet.

The CGSE-ES will be installed in five electronics racks with overall dimensions .6 m x 1.6 m x .6 m. The weight of the electronics racks is less than 200 kg. The power supply is less than 2 kW, 220 V, 50 Hz. The CGSE-ES will be used in the SSPF and on the launch pad.

CGSE: Monitoring and Control General Scheme

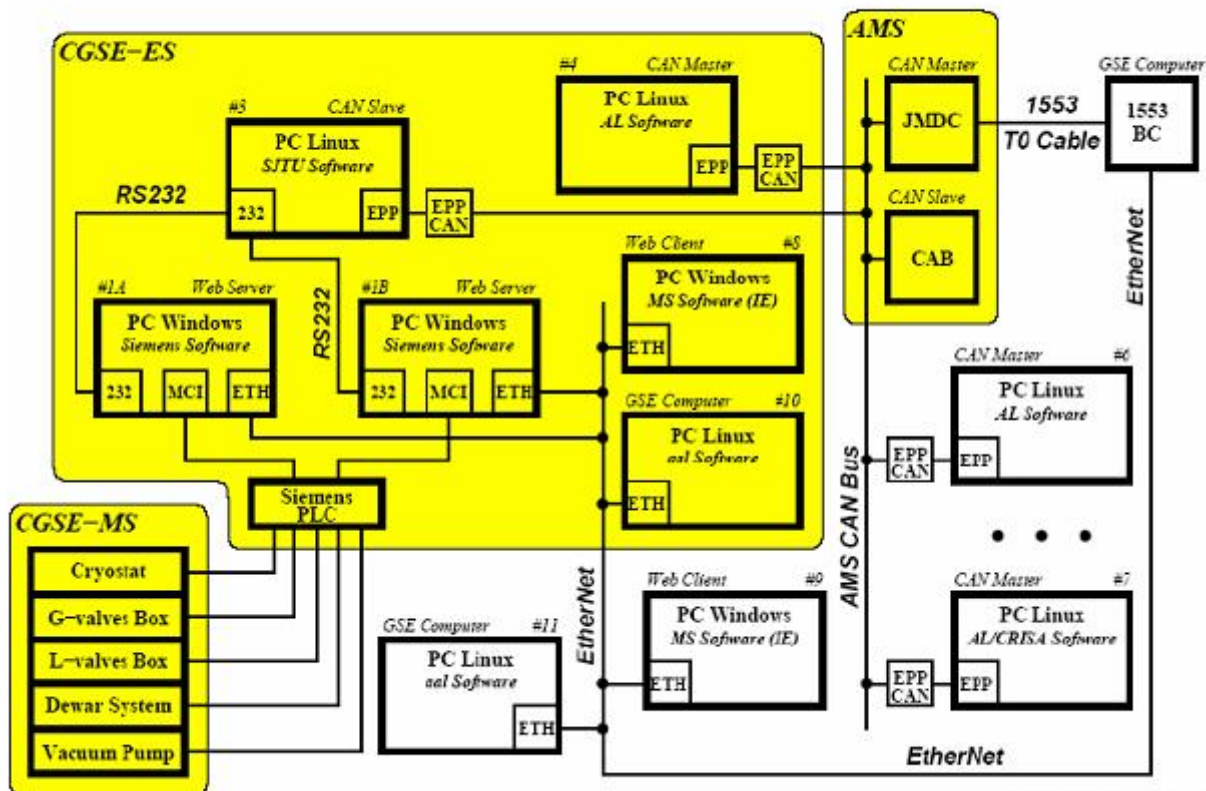


Figure 5.1.12-1 CGSE Monitoring and Control General Scheme



Figure 5.1.12-2 CCGSE Control System

5.1.13 The Helium Leak Detector

The helium leak detector is a standard commercial unit used to ensure all payload and CGSE hardware connections are leak tight prior to operation. It is an Inficon UL 1000 (dimensions .11 m x .53 m x .85 m, 110 kg) and will be used during off-line testing in the SSPF and before top-off on the pad. The leak detector requires a helium gas source provided by KSC. The lines and regulators are provided by the project. Power requirements for the detector are 100-120 V (220-240 V with a transformer)

5.2 TRD GSE

The TRD GSE includes two separate systems. The first is a passive TRD pressure stabilization system and the second is the xenon and carbon dioxide supply filling system.

5.2.1 Passive TRD Pressure Stabilization System

The passive TRD pressure stabilization system (Figure 5.2.1-1) consists of:

- A small (10 l) commercial bottle rated at 200 bar with a proof pressure of 300 bar. It is filled with Xe/CO₂ at a pressure of 70 bar, sufficient for re-supplying gas losses through one ruptured straw for 20 weeks.
- A pressure reducer with an output range of 0 to 2 bar overpressure (reducer may be reduced to 0-1 bar overpressure).
- A GMH 3150 battery operated pressure sensor display and logging device (for data keeping purposes only).

The system is used to keep the straws inside the TRD from collapsing by keeping them 100 mbar above the atmospheric pressure. It will be connected to the TRD system before arriving at KSC and remain connected during ground processing. Pressure from the CO₂ tank is regulated by the pressure reducer, which is set to 1140 mbar abs. When TRD internal pressure falls below the pressure reducer setting, CO₂ from the supply bottle will increase the pressure so that it maintains the 100 mbar overpressure requirement. This system will be removed before flight, shortly before payload bay door closure.

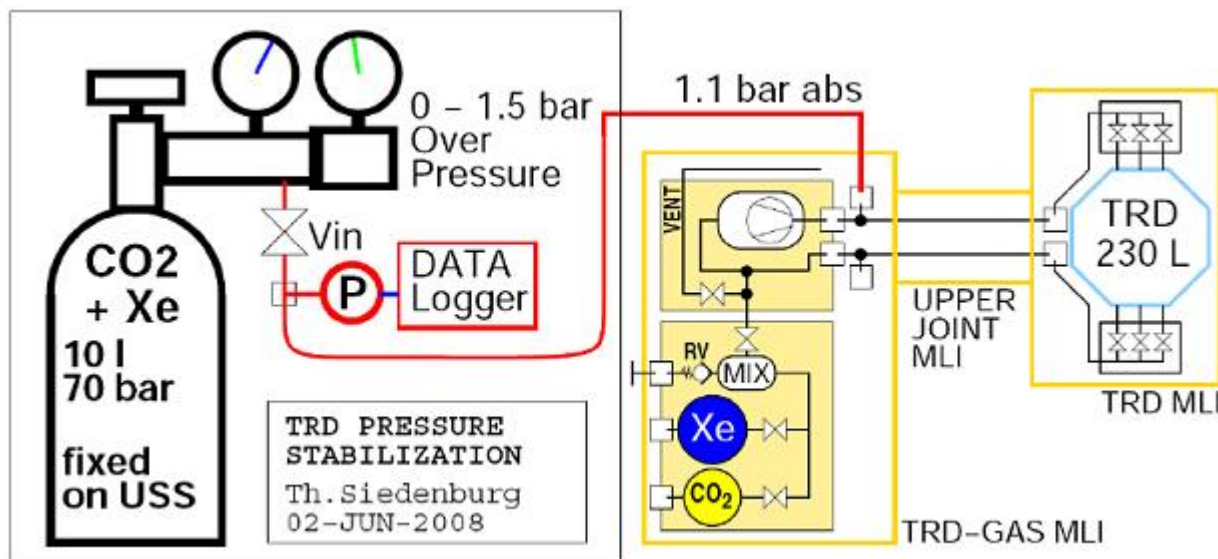


Figure 5.2.1-1 Schematic of TRD Pressure Stabilization System

5.2.2 Xenon and Carbon Dioxide Supply Filling System

The xenon and carbon dioxide supply filling system (Figure 5.2.2-1) consist of the following components:

- One 50 l CO₂ bottle.
- One 1-3 l Xe bottle.
- One temperature controller with heating tape and a temperature sensor (Horst HT31 controller).
- A pressure reducer with an output range of 10-100 bar.
- A scale for weighing the tanks.

The system will be used at KSC only if contingency recovery is necessary. The method of transfer of Xe and CO₂ from the storage tanks to the Box-S supply vessel will be by boiling off some of the gas from the supply tank and letting it condense in the supply vessel. The power requirement for the system is approximately 220 V, 1.8 A, 0-400W for the heater tape.

Maximum fill of the flight tanks is controlled by the molar fill quantity of the source tanks and the need for thermal loading of the source tank to get the pressure curves necessary to affect transfer.

All valves are operated manually by a team of two operators cross-checking each other. They are present the whole time the system is connected to the supply vessels or when the heaters are powered.

The source bottle temperature is measured three times: 1) by the heater control unit (with display) that is used to switch on power to the heater tape; 2) by a thermometer with display; and 3) by a thermo-sensor read by the PC monitor. The line pressure is measured six times: 1) with manual gauges at the pressure reducer; 2) with P_{man}, P_i, and P_o which are read by the monitor and 3) the two supply-vessel pressure sensors from the TRD gas system.

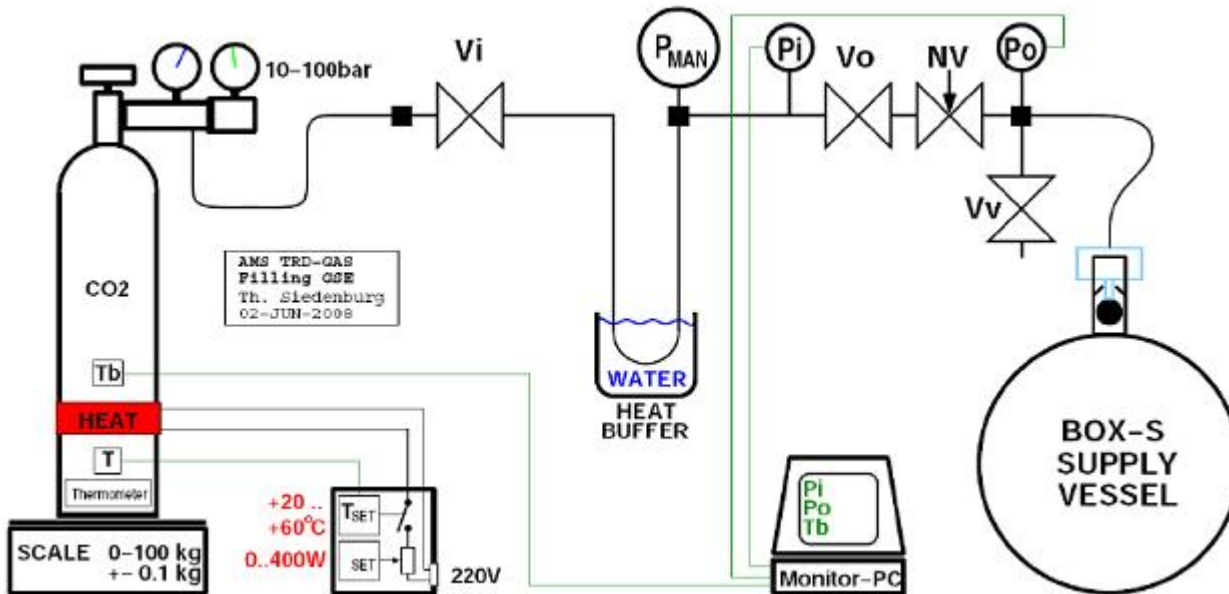


Figure 5.2.2-1 Xenon CO₂ Supply Filling System (CO₂ Xenon System the Same)

5.3 Warm Helium Gas System GSE

The warm He gas system GSE consists of a regulator valve, a 300 bar pressure relief valve, a 2 μ m filter, a pressure gage, and a vacuum pump. Figure 5.3-1 is a preliminary design. The system will hook up to a KSC supplied helium source (MIL-P-27407 grade) and transfer gaseous helium to the AMS-02 warm helium gas supply bottle. A final design, system specifications, and criteria for refilling are TBD.

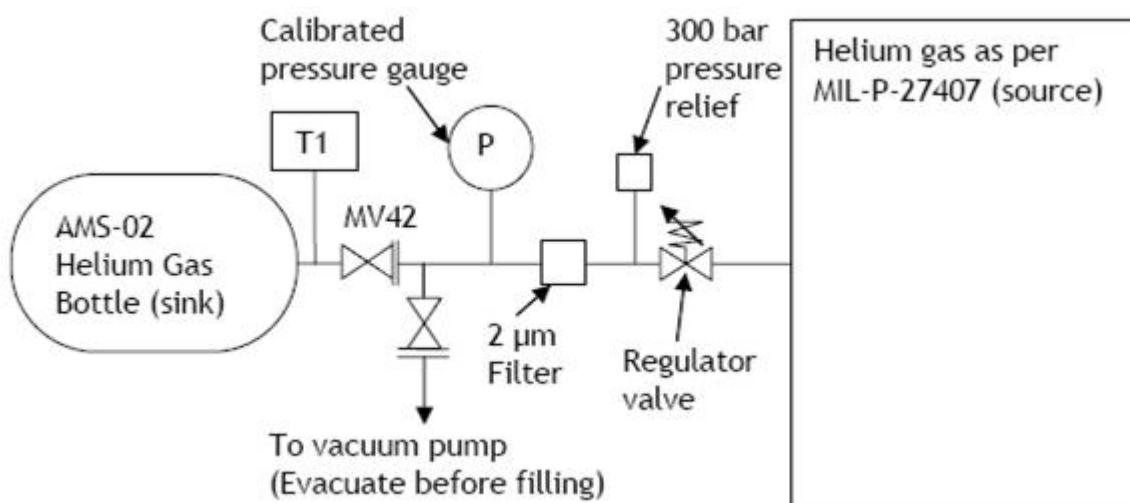


Figure 5.3-1 Warm He Gas System GSE Schematic
(KSC filling system will likely be similar)

5.4 TCS GSE

The TCS GSE consists of 12 type A fans and three type B fans. The following are the specifications for each type of fan:

- Type A Fans
 - Diameter: >.45 m
 - Flow Rate: 4100 m³/hr
 - Power: 135 W
 - Voltage: 110 V
 - Frequency: 60 Hz
- Type B Fans
 - Diameter: >.18 m
 - Flow Rate: >740 m³/hr
 - Power: 50 W
 - Voltage: 110V
 - Frequency: 60 Hz

The first set of four type A fans will provide ventilation to the electronic units mounted on the Ram radiator. The second set of type A fans will provide ventilation to the electronic units mounted on the Wake radiator. The third set of four fans will provide ventilation to the zenith radiator.

One type B fan will be dedicated the PDS. The other two type B fans will be used to provide ventilation to the CAB.

All fans will be commercial off the shelf (COTS) and have the European “CE” quality symbol on it. The supplier of the fans is TBD.

5.5 AMS-02 GPS Ground System Test Equipment

The GPS ground system test equipment (Figures 5.5-1—5.5-3) is used to test the AMS-02 GPS. It consists of a Spirent STR4500 GPS signal simulator, a Dell D620 Notebook computer, a GPS passive antenna, an attenuator, a radio frequency (RF) coaxial cable and a universal serial bus (USB) cable.

The equipment will be used in two configurations. The first will be with the simulator hooked up directly to the AMS-GPS receiver via a coaxial cable with the Notebook connected to the simulator

via a USB cable. The second configuration uses a GPS passive antenna hooked up to the simulator via an RF coaxial cable, with the simulator hooked up to the Notebook via a USB cable. A GPS signal is sent through the passive antenna to the AMS GPS antenna. The distance between the antennas is less than 1 m. Testing will only occur in the SSPF.



5.5-1 GPS Simulator and Dell Notebook Computer

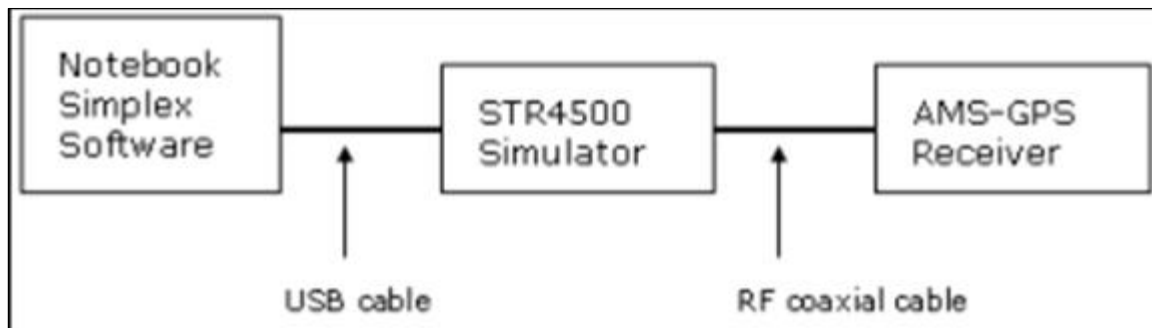


Figure 5.5-2 First Test Configuration

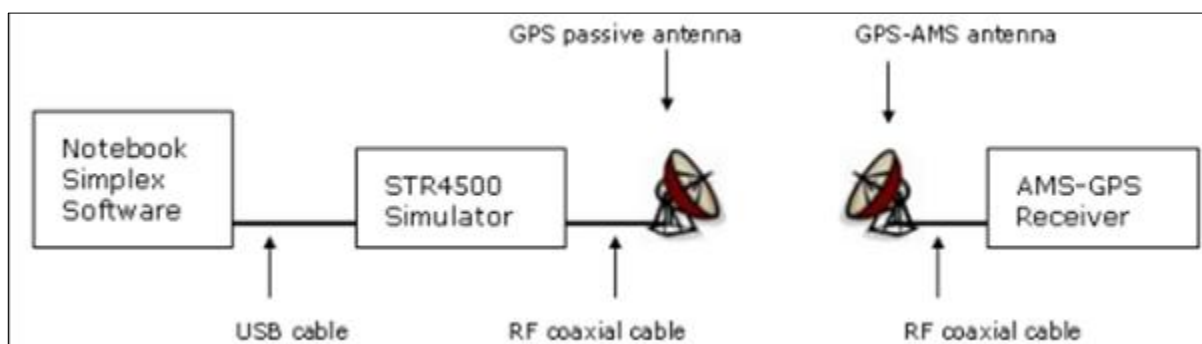


Figure 5.5-3 Second Test Configuration

The output frequency for the STR4500 simulator is 1575.42 MHz. The antenna has a frequency range of 157542 GHz + 1,023 MHz. Its amplification is 26 Db + 3Db. The attenuator has an attenuation of 0-60 Db with 10 Db step.

5.6 Star Tracker GSE

The Star Tracker GSE consists of a PC computer, an emulator, and an illumination source to check the tracker cameras. Further details are TBD.

5.7 Ground Handling Equipment (GHE)

The AMS-02 GHE that will be used at KSC consists of the Primary Support Stand (PSS), the Lower USS Shipping Assembly, the Primary Lifting Fixture (PLF), the Multi-Purpose Lifting Fixture (MPLF), and four Intermediate Support Fixtures (ISF's) (contingency use only).

5.7.1 Primary Support Stand (PSS)

The AMS-02 PSS has three functions. It will be used as a transportation fixture for the AMS-02 payload for airplane travel from Europe to KSC and travel/relocation at KSC. Second, it is a support stand for the AMS-02 payload during assembly, testing and integration. Third, it can support the AMS-02 payload during required lifting operations.

The PSS is made of 6061 aluminum and measures 195.0 in. x 135.7 inches x 125.0 inches in its “high” configuration and 195.0 inches x 114.9 inches x 125.0 inches in its transport or “low” configuration.

The PSS will be in two different configurations while at KSC. It will arrive supporting the upper part of AMS-02 in the “low” configuration. It will have a cover assembly and shipping panels attached to it that keeps AMS-02 safe from the elements. The cover assembly and 23 panels are of various sizes and are made of Alupalite—an aluminum composite panel with a high density, corrugated polyallomer (CPA) core.

Sometime after arrival, the PSS will be converted from its “low” configuration to its “high” configuration. First, four rail extensions assemblies are installed on top of the PSS. Four brace assemblies are then installed to accommodate the PSS in its “high position”. The longitudinal and lateral tie-bar assemblies are installed next. The PLF then raises the sliding frames, along with the upper USS-02 and the flight hardware installed on it, to the “high” configuration. Internal diagonal

assemblies are installed, completing the PSS conversion. Ground personnel will then be able integrate the upper USS, the lower USS, the keel, and the Payload Attach System (PAS). Any further transport of the PSS while at KSC will be done in the “high” configuration. Figures 5.7.1-1 through 5.7.1-9 illustrate the PSS conversion process.



Figure 5.7.1-1 PSS in “Low” Configuration with Upper USS-02 and Vacuum Case

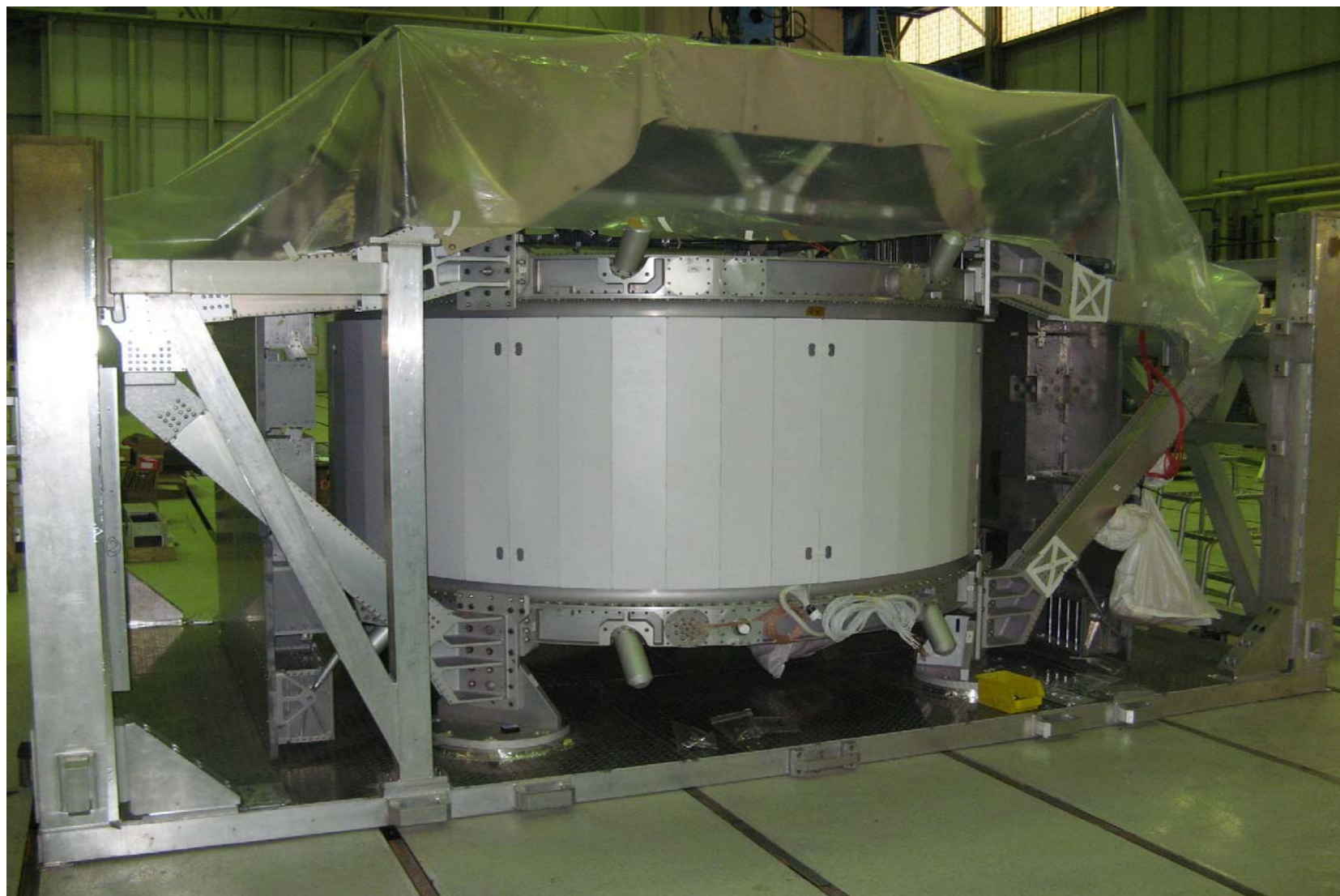


Figure 5.7.1-2 PSS with Longitudinal Members Removed



Figure 5.7.1-3 Installing 1 of 4 Rail Assemblies



Figure 5.7.1-4 Installing 1 of 4 Brace Assemblies



Figure 5.7.1-5 Installing 1 of 2 Longitudinal Tie Braces



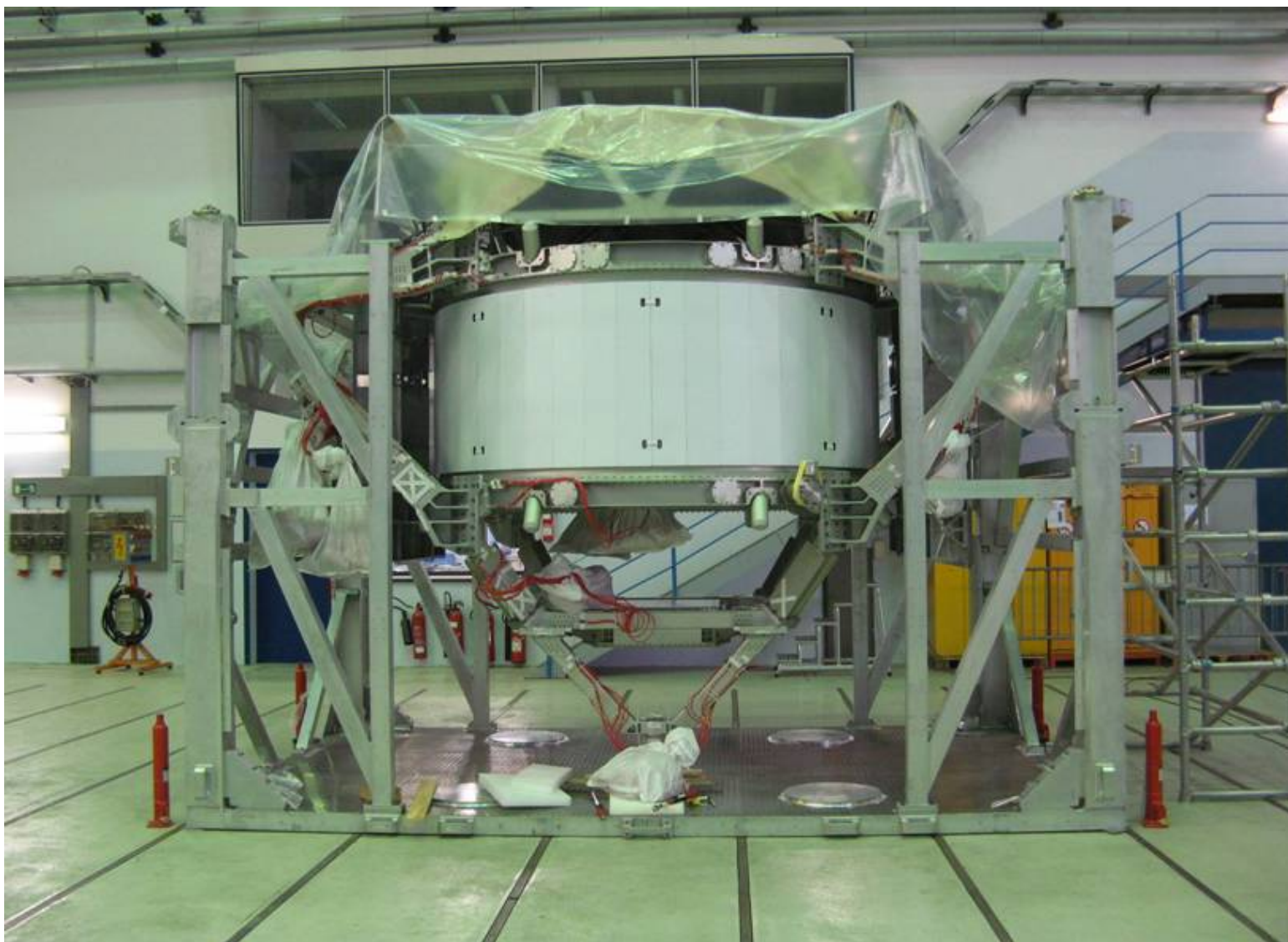
Figure 5.7.1-6 Installing 1 of 2 Lateral Tie Braces



**Figure 5.7.1-7 Raising the Sliding Frames and the USS-02
(with AMS-02 attached) to the “High” Configuration**



Figure 5.7.1-8 Installing 1 of 4 Internal Diagonal Assemblies



**Figure 5.7.1-9 Lower USS and Keel Attached to Upper USS-02
(PAS not shown)**

5.7.2 Lower USS (LUSS) Shipping Assembly

The lower USS (Figure 5.7.2-1) will arrive at KSC in its own shipping assembly. It is 127.25 in. x 97.7 in. x 12.5 in. and is made of 6061 aluminum. It also serves as the lower USS support stand while it is being integrated to the upper USS.

Figure 5.7.2-1 LUSS Shipping Assembly with LUSS and Shipping Panels

5.7.3 Primary Lifting Fixture (PLF)

The PLF (Figure 5.7.3-1) is a hoisting assembly made of A-36 steel/carbon steel with maximum dimensions of 190.8 in. x 123.8 in. x 187.4 in. It will be used in three ways: 1) it will lift the PSS after its arrival at KSC; 2) it will lift the PSS into the two different heights needed for the assembly of the AMS-02 payload at KSC and; 3) it will lift the entire payload out of the PSS and into the KSC stands.

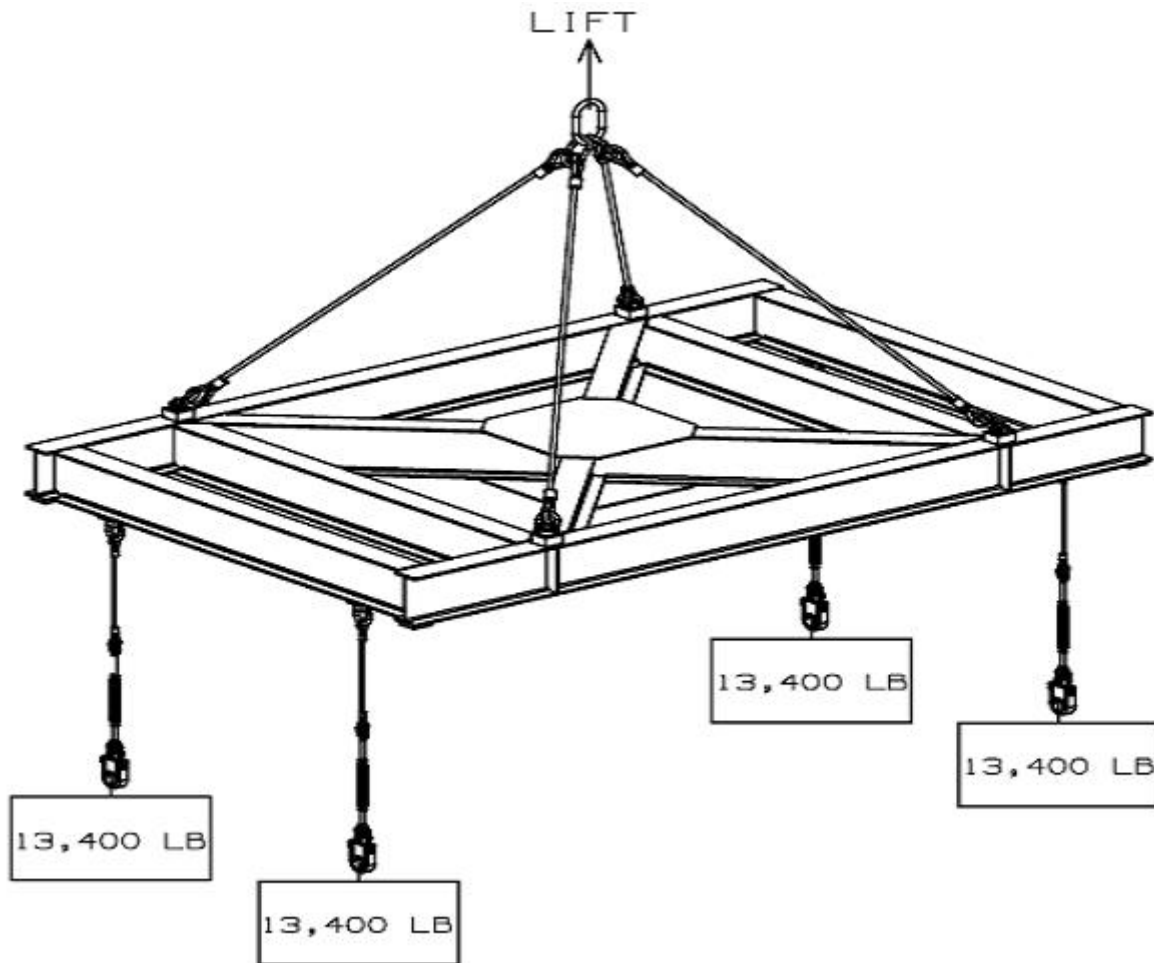


Figure 5.7.3-1 Primary Lifting Fixture (PLF)

5.7.4 Multi-Purpose Lifting Fixture (MPLF)

The MPLF (Figure 5.7.4-1) is a hoist assembly made of A-36 and carbon steel and measures 125.3 in. x 109.0 in. x 242.3 in. It has three functions: 1) it lifts the lower USS shipping assembly during the removal and integration of the lower USS to the upper USS; 2) it lifts the PSS top frame before and after it is transported; and 3) it lifts the VC for removal and integration into the upper USS (this function is not anticipated to occur during KSC operations)

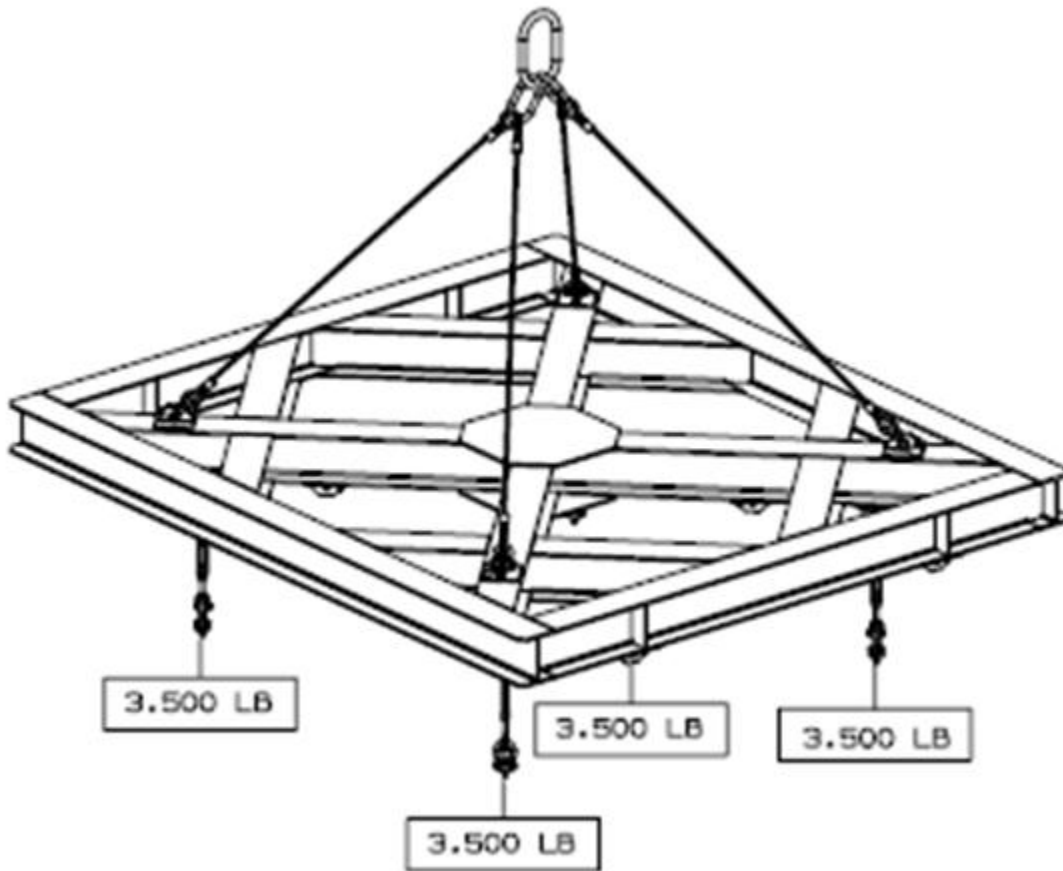


Figure 5.7.4-1 Multi-Purpose Lifting Fixture (MPLF)

5.7.5 Intermediate Support Fixtures (ISF's)

There are four ISF's (Figure 5.7.5-1) included in the AMS ground-handling equipment. They are made of aluminum 6160 and measure 45.5 in. x 13 in. x 4 in. The ISF's are bolted to the upper and lower joints of the USS-02 in order to guide the VC when it is being installed into the USS-02. They are only used for contingency purposes and not expected to be used at KSC.

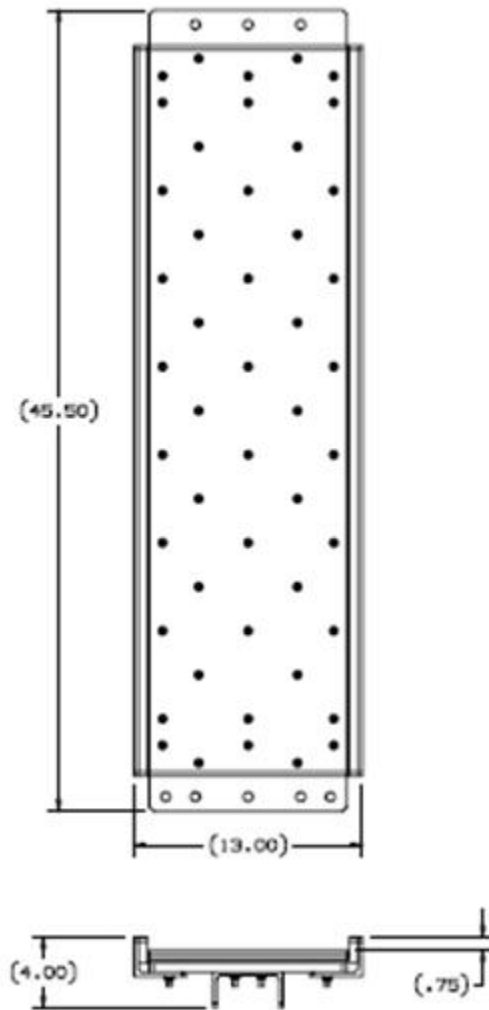


Figure 5.7.5-1 Intermediate Support Fixture (1 of 4)

5.8 Electrical GSE (EGSE)

The EGSE for AMS-02 is COTS. A detailed list of the AMS-provided EGSE is provided in Table 5.8-1.

Table 5.8–1 AMS-Provided Electrical Equipment

Location	Item	Manufacturer	Model Number	Commercial Yes/No	Electrical Code	3-Phase Yes/No	Batteries Yes/No Commercial/Custom	Functions	Quantity
<u>Diagnostic</u> (used wherever needed)									
	1	Tektronix	TDS 7054	Yes	UL	No	No	Oscilloscope	1
	2	Tektronix	TDS 11402	Yes	UL	No	No	Oscilloscope	1
	3	Fluke, etc.	Multimeters	Yes	N/A	N/A	Yes, Commercial	Multimeters	5
<u>EGSE</u> (mounted near or on payload during ground operations in SSPF, not used in PCR (TBC))									
TBC	4	Honeywell	HV180	Yes	UL	No	No	Fan for main radiator cooling	8
TBC	5	Honeywell	HV180	Yes	UL	No	No	Fan for Zenith radiator cooling	4
TBC	6	Honeywell	HT800-E	Yes	CE/GS	No	No	Fan for PDS and CAB cooling	3
	7	Texas Instruments	UNK	Yes	CE	No	No	AST LED	1
	8	Spirent	STR4500	Yes	CE	No	No	GPS simulator	1
	9	MIDWEST MICROWAVE	STA-1043-04-NNN-79	Yes	CE	No	No	GPS Attenuator	1
	10	planTec	UNK	Yes	CE	No	No	GPS simulator transmitter	1
<u>GSC</u> (located near payload during ground operations, e.g., on tables in SSPF High Bay or in MLP)									
	11	Hewlett-Packard	DC7700-CMT	Yes	UL	No	No	Personal computer (POC/GSC)	2
	12	Hewlett-Packard	DC7800-CMT	Yes	UL	No	No	Personal computer (POC)	2
	13	Hoojum Design	Cubit3	Yes	UL	No	No	Personal computer (GSC)	4
	14	Agilent Technologies	N5770A	Yes	UL	No	No	DC power supply (120V)	4
	15	D-Link	DGS-1016D	Yes	UL	No	No	Gigabit network switch	1
	16	3Com	4400 24PT	Yes	UL	No	No	10/1000 network switch	1
	17	NEC	Multisync LCD2170NX	Yes	UL	No	No	LCD Monitors	2
	18	Dataprobe	iBB-2N20	Yes	UL	No	No	Remote reboot power outlets	2
	19	AMS	EPPCAN	No		No	No	EEPCAN interface, 5V	2
	20	AMS	USB422	No		No	No	RS422-USB interface (DDRS)	2
<u>POCC</u> (located in "user area" for controlling the payload during ground operations)									
	21	Hewlett-Packard	DC7700-CMT	Yes	UL	No	No	Personal computer (POC/GSC)	4
	22	Hewlett-Packard	DC7800-CMT	Yes	UL	No	No	Personal computer (POC)	2
	23	D-Link	DGS-1016D	Yes	UL	No	No	Gigabit network switch	1
	24	3Com	4400 24PT	Yes	UL	No	No	10/1000 network switch	1
	25	NEC	Multisync LCD2170NX	Yes	UL	No	No	LCD Monitors	13
	26	Dell	PowerEdge 2900 III	Yes	UL	No	No	Personal computer (SOC)	2
	27	Dell	Dell Power Vault DP 600	Yes	UL	No	No	Disk server (POC)	1
	28		UPS	Yes	UL	No	Yes, Commercial	UPS for disk server	1
	29	Hewlett-Packard	Laserjet printer	Yes	UL	No	No	Network printer	1
<u>CGSE</u> (CGSE that uses electricity directly, all needed at SSPF and in PCR)									
	30	Leybold Vacuum	RUTA 2001	Yes	CE	YES	No	Main Vacuum Pump	2
	31	BOC Edwards	XDS5	Yes	CE	No	No	PVVV Vacuum Pump	1
	32	Infincon	UL 1000	Yes	CE	No	No	He leak detector	1
	33	DAIKIN EUROPE NV	EUWAB8KAZW1 -- G	Yes	CE	Yes	No	Chiller for PCR??	1
<u>E-CGSE</u> (electronics associated with CGSE, located nearby in 5 enclosed 19" racks, ~2ftx2ftx5ft, e.g. on floor of SSPF or in PCR)									
	34	APC	2200UX Smart UPS	Yes	UL	No	Yes, Commercial	UPS for CGSE	2
	35*	Le Guan	Lead-Acid Battery Pack	Yes	UNK	No	Yes, Commercial	UPS for CGSE	2
	36	ADVANTECH	610H	Yes	CE	No	Yes, Commercial	Industrial PC for CGSE	3
	37	ADVANTECH	AWS-8259TP-T	Yes	CE	No	Yes, Commercial	Industrial PC Display	3
	38	SIEMENS	PanelPC 557	Yes	CE	No	Yes, Commercial	Industrial PC for CGSE	1
	39	SIEMENS	FieldBus Modules	Yes	UL	No	No	PLC crates for CGSE	10
	40	Scientific Insturements	9350-1	Yes	UL	No	No	Temperature Indicator	1
	41	Yudain	UNK	Yes	CE	No	No	Alarm MUX?	1
	42	TPLink	UNK	Yes	CCC	No	No	Ethernet hub	1
	43	AMI	135-2K	Yes	CE	No	No	Liquid He level probe	1
	44	Shanghai YunJie Vacuum Equip.	2DF-1B	Yes	UNK	No	No	"Complex Vacuum Meter"	1
	45	TBD	Transformer	Yes	UL	No	No	110-220V transformer	3
	46	AMS	EPPCAN	No		No	No	EEPCAN interface, 5V	2
<u>E-CGSE</u> (electronics associated with CGSE, mounted onto the CGSE elements themselves)									
	47	SIEMENS	FieldBus IO Modules	Yes	UL	No	No	CGSE Monitoring & Control	~30
	48	TBD	FieldBus IO Modules	Yes	UL	No	No	CGSE Monitoring & Control	~20
<u>Offices/POCC</u> (wherever people can find to sit and work)									
	49	Various	Laptop computers	Yes	UL	No	Yes, Commercial	Laptop computer	40
	50	Hewlett-Packard	Laserjet printer	Yes	UL	No	No	Network printer	1

* Not used at KSC

5.9 KSC Supplied GSE

The following is a list of KSC supplied GSE for the CGSE:

- Two 120 VDC Power Supply in MLP Room 10A
- LHe -7500 l*
- LN2 -3000 l *
- High purity gaseous helium (He>99.999%)-24 40 l bottles (200 bar rated)
- electrical power consumption-62 kW **
 - Including vacuum pumps (per pump) -22.5 kW, 400V, 50 Hz or 2x27 kW 460V, 60 Hz
 - Membrane pumps (4)-1 kW (230/400V, 50/60 Hz) per pump
 - Heaters-6 kW (220V, 50/60 Hz) ***
- Total CGSE test area-80 m2

*Total LHe and LN2 consumption with losses in case of cooling AMS from room temperature to 1.8 K and filling 100 % of the AMS with SFHe.

**Power consumption of computer control system and air compressor for valve pneumatic system is not included.

***Heaters can be replaced with fans.

Requests for other KSC-supplied GSE are pending.

6 Operations Summary

The following represents a summary of AMS-02 operations at KSC. It is a top-level description describing the flow of operations from the time GSE and AMS-02 arrives at KSC through AMS-02 being placed into the orbiter. There is also a short section covering contingency operations.

6.1 Pre-Payload Arrivals

Certain GSE will arrive at KSC before AMS-02.

6.2 Payload Arrival

AMS-02 and its GSE will arrive at KSC in FY 2009 be delivered at approximately L-4.5 months.

The majority of AMS will likely arrive by airplane at the shuttle landing facility. Other components will arrive by truck.

6.3 SSPF Activities

SSPF activities will begin with the arrival of hardware into the SSPF airlock and proceed to footprint 7 where AMS-02 is to be processed. The activities within the SSPF include the following:

- Hardware unpacking, set-up, and cleaning.
- GSE assembly.
- CGSE integrated with AMS-02.
- Attach LUSS to USS.
- Hardware Installation
 - Grapple Fixtures
 - Wiring Panels
- Remove AMS-02 from PSS.
- Lift AMS-02 to ELC Rotation Stand.
 - EBCS alignment
 - ACASS fit check
- ISS Interface Verification Testing (IVT) [Power and Data]
- Remove AMS-02 from ELC—install back into PSS.
- Re-connect CGSE to AMS-02.
- Functional testing while AMS-02 magnet is charging (TBR).
- Continue to fill/cool AMS-02 with CGSE.
- Word comes to take AMS-02 to the launch pad.
 - CGSE transferred to PCR.
 - AMS-02 placed in Canister and taken to CRF.

6.4 CRF Activities

- Canister Operations (possibly including operation of on-board vacuum pump).

6.5 PCR Activities

- Install CGSE

6.6 Orbiter/Pad Activities

- STS IVT [Power and Data]
- SOO24

- Payload arrives at Pad/PCR after SOO24.
- Connect CGSE to AMS-02 after AMS-02 is placed in the Orbiter.
- Final top off of AMS-02 at L-88 hours (**May** require top-off immediately after payload arrival to troubleshoot technique).
- Clear Pad by L-80.
- On-board pump (OBP) turned on.
- Disconnect CGSE from AMS-02.
- PLB doors closed.
- Ground Operations/Maintenance.
- OBP off at L-30 min.
- Monitor until L-9 min.

6.7 Contingency Operations

- Scrub +120 hours
 - Re-connect CGSE to AMS-02.
 - Cool down LHe tank.
 - Top off for next launch.
- Rollback (for hurricane or other contingency in which AMS-02 must go without services.)
 - Disconnect CGSE from AMS-02.
 - Orbiter is rolled back from the pad.

7 Safety Discussion

A safety analysis was performed for the AMS-02 GSE, GHE, and KSC ground operations using KHB 1700.7C to identify potential hazards. The analysis covered all identified ground operations at KSC including payload handling, payload assembly, payload servicing payload checkout, and contingency scenarios. The analysis for the AMS-02 ground safety package has resulted in the production of 17 unique hazard reports. What follows is a summary of the hazard analysis by hazard category.

7.1 Fire

Hazard causes that could lead to a fire either from AMS-02 flight or ground hardware include improper use of flammable material, electrical causes, and mechanical failures.

In order to control these hazards, flammable material use has been kept to a minimum. Any flammable materials that will be used by the AMS-02 project will be submitted to the Customer Integration Manager. In addition, any plastics, adhesive tapes, or foams will be used only with the concurrence of KSC.

Any potential ignition sources on either the payload or its GSE will either be labeled or shielded. In the case of electrical ignition sources, all electrical circuits will be designed with proper wire sizes and overload protection devices. Electrical connectors will be designed to make it physically impossible to mismatch. In addition, proper mating/de-mating procedures will be performed to prevent any arcing and sparking. Mechanically, rotating equipment will be properly cooled, either with air or water cooling systems. Rotating parts will be properly lubricated to minimize heat build-up. In addition, components will be sized for the appropriate function they are to perform.

The hazard causes and controls for fire have been addressed in GHR-AMS-02-001.

7.2 Toxicity

Any toxic materials that are used will be controlled either through proper containment and/or procedure. Any solvents or adhesive materials will be contained in National Fire Protection Agency (NFPA) -approved containers. Toxic materials will only be handled by trained personnel using procedures approved by the KSC Biomedical Office and the Launch Site Safety Office (LSSO).

The hazard cause and controls for toxicity have been addressed in GHR-AMS-02-002.

7.3 Liquefaction of Atmospheric Gases

AMS-02 uses a cryogenic system to super-cool its magnet. While on the ground, superfluid helium will be pumped into the AMS-02 via the CGSE. With the use of a cryogenic system comes the hazard of the liquefaction of surrounding atmospheric gases. These liquefied gases then have the potential of coming into contact with incompatible materials causing injury to personnel and damage to the payload and its GSE and surrounding GFE.

There will be three approaches to controlling this hazard. First, the cryogenic systems will be properly insulated in order to prevent contact with the surrounding atmosphere. Second, for those areas that cannot be sufficiently insulated, containment in the form of catch pans and absorbent “diapers” will be used to prevent liquefied gases from coming into contact with incompatible

materials. Third, materials that will be used close to cryogenic systems will be selected only if they are compatible with liquefied atmospheric gases.

The hazard causes and controls for liquefaction of atmospheric gases have been addressed in GHR-AMS-02-003.

7.4 Pressure Systems

There are a variety of different pressure systems on the AMS-02 payload and its associated GSE. Hazards covered for these systems include personnel error, freezing of the cryogenic vents and lines, puncture of the VC or GSE vacuum shrouds, materials incompatibility, and COPV damage.

Personnel error includes such causes as over-pressurization/overfilling and mishandling of the pressure vessels as well as improper workmanship or assembly. Controls will include observance of proper filling procedures, correct handling of the pressure vessels, and the use of pressure relief devices to prevent over-pressurization. The systems will be built to controlled drawings and quality assurance procedures to ensure proper operation.

Freezing of the vents and freezing/thawing of the cryogenic pressure system could either cause over-pressurization or breaches in the system. Controls include using the vacuum pumps to keep atmosphere out of the cryogenics lines. The helium used will meet or exceed purity standards of MIL-P-27407 and will be filtered to remove particles.

Puncture of either the VC or GSE vacuum shrouds could cause over-pressurization of the cryogenic system. Both shrouds are designed to preclude puncture from falling objects.

Materials incompatibility could lead to deterioration of a pressure system. The design of each system precludes such deterioration by ensuring the system's materials are compatible with what it will hold.

COPV damage through accidental handling or falling objects raises uncertainty as to its structural integrity. The COPV's on AMS-02 will have temporary shields during ground handling as well as permanent MMOD shielding.

There also exists the hazard of damaging the COPV's by over-pressurizing them during a fill procedure. The hazard is controlled by using CO₂ and Xe refill bottles that will contain gas pressurized well below the MDP of the COPV's (206 bar (3000 psi)). There are also pressure

reducers (10-100 bar) connected to the refill bottles that keep the pressure in the system below the MDP of the COPV's

The hazard causes and controls for pressure systems have been addressed in GHR-AMS-02-004.

7.5 High Pressure Gas

With the variety of pressure systems associated with AMS-02, there is the hazard of personnel being exposed to gas plumes. Such a hazard could lead to asphyxiation, high velocity gas, projectiles, and/or touch temperature hazards. The hazard could come about due to equipment or personnel error, normal fill/transfer operations, or due to improper handling or assembly.

In order to control equipment failure or operator error, a variety of controls will be used. Vents and relief devices will direct vented gas out of the AMS-02 work area. Shields and deflectors will be put into place to prevent personnel from being fully exposed to plumes. Labels will warn personnel of potential gas plume locations.

During normal operations, personnel will wear Personal Protective Equipment (PPE) to prevent full exposure to gas. Training will be provided on proper filling procedures. Labels will warn of potential vent areas. There will also be clear indications of when filling operations are taking place. To avoid mishandling or assembly of gas or cryogenic systems, proper assembly and operating procedures will be followed.

The hazard causes and controls for pressure systems have been addressed in GHR-AMS-02-005.

7.6 Touch Temperatures

Either excessively low (below 32°F or 0°C) or excessively high (above 113° F or 45° C) surface temperatures on certain components of AMS-02 will create a touch temperature hazard for ground personnel.

Cold touch temperatures are associated with the cryogenic systems and their GSE. The hazard is controlled primarily through insulation of the cryogenic system. For those areas that cannot be insulated, atmospheric gases might liquefy and come into contact with payload or GSE surfaces. Diapers and catch pans will be used in such instances to prevent such contact. In the case of released cryogenic materials, vents are positioned to preclude cryogenic gas contact with payload or GSE surfaces. To preclude the formation of ice, heaters/fans will be used to keep exposed areas

warm. Warning signs will be placed where ice might accumulate to alert personnel to stay clear of the affected areas. The cryogenic systems will also be monitored by trained personnel to detect leaks and apply corrective measures.

The hazard causes and controls for cold touch temperatures have been addressed in GHR-AMS-02-006.

Hot touch temperatures are associated with the various pumps (the vacuum pumps being the biggest concern), dump diodes, and heaters on the TRD K-bottle (cf. Figure 5.2.2-1). The large vacuum pumps will be cooled via a water coolant system while the others will be air cooled. The dump diodes, which convert electrical energy to heat during a nominal discharge of the magnet, are located in an area out of reach of personnel. They are also shielded in an enclosure and are insulated. When the magnet is charged, personnel are not allowed in the immediate area, thus further reducing the likelihood of a hazard. The TRD heating tape has the capability of heating the surface temperature of the K-bottle above 113° F when the bottle is near empty. Controls for the tape include proper setting of the temperature controller, a temperature sensor, and the use of a frame to keep personnel away from the bottle.

The hazard causes and controls for hot touch temperatures have been addressed in GHR-AMS-02-015.

7.7 Loss of Breathable Atmosphere

Due to the presence of oxygen displacing gases in the AMS-02 and GSE, a loss of breathable atmosphere could occur either in the immediate vicinity of the payload, the building, or the container in which it is housed.

In the event of oxygen displacing gases being released from AMS-02 or its GSE, ventilation will be used to aerate the surrounding volume. Oxygen sensors will monitor any areas where these gases may accumulate. Personnel will be trained regarding evacuation procedures in the event of a significant gaseous release by the AMS-02 and/or its GSE..

Injury due to prolonged activity close to venting gases will be controlled by requiring a minimum of two people working in the payload area at one time (the buddy system). Labels will indicate where gases may vent. Furthermore, nominal operations will not occur near venting areas.

There is particular concern of an oxygen displacing gas venting in the canister that takes AMS-02 to the pad. This will be precluded by venting and inspection of the canister atmosphere for adequate oxygen levels prior to allowing personnel into the canister.

An analysis of oxygen depletion during failure scenarios has been made for operations at the SSPF, the launch pad, and during moves. The flight helium tank/vacuum case was the focus of the analysis due to it being the container with the greatest volume of superfluid He (2500 liters). The following were assumptions made in the analysis:

- Helium exiting the vent in the Vacuum Cases has already expanded to ambient temperature and pressure. Density is therefore at its minimum possible value and volume displacement is maximized.
- The exiting helium instantaneously and completely mixes with the air in the room. It is not assumed to stratify and rise to the ceiling.
- Overall change in air pressure and density from the vented helium is assumed to be negligible.

The potential failure used for the analysis was termed the Maximum Credible Leak. The scenario chosen was adjacent 3” wide pinches in the double O-ring seals surrounding the main dewar. If the fastener closest to the pinches was to fail, a gap of .001” could open up, creating a .003 in² hole in the dewar. For conservatism, it was assumed that the hole was circular, minimizing boundary layer effects on the airflow into the dewar. Although originally developed for flight, the Maximum Credible Leak is equally reasonable for ground operations.

The analysis for the SSPF interior volume concluded that oxygen levels will not fall below 19.5% (Oxygen percentage required by the Occupational Safety and Health Association (OSHA)) in the facility, thus no general asphyxiation hazard. Discussions amongst the payload organization have concluded that- based on these results—no emergency vent lines will be necessary during any AMS-02 ground operations in the SSPF. Since helium rises, however, caution needs to be exercised by personnel who go up into the upper bay of the SSPF so that they will not walk into an oxygen deficient atmosphere.

After checkout in the SSPF, the AMS-02 is disconnected from its GSE and is placed in the canister for delivery to the CRF. While being transported in the canister, flight hardware will be in the transport configuration and will require nominal venting/evacuation of the helium tank. Any helium gas from the tank is not anticipated to build up to any appreciable level under nominal operations. If the AMS-02 is required to stay in the canister longer than planned, a pressure relief (“burp”) valve

has been provided for in the flight system to preclude the pressure of the tank from exceeding MDP. The AMS-02 Project will have monitoring capabilities and may request the vehicle to stop if it detects a large-scale release of helium.

The nominal venting of helium gas will not displace breathable atmosphere within the canister. Venting due to fault conditions that result in a burst disk could in theory displace the breathable atmosphere within the canister, however. The potential build up is controlled by the environmental system that exchanges air within the canister. If AMS-02 has to be left dormant or unattended in the vehicle, oxygen sensors will be used prior to entry into the canister.

The canister is transported from the SSPF to the CRF for further processing before proceeding to the Pad. The analysis for the CRF interior concluded that oxygen levels will not fall below 19.5%. As with the SSPF, the volume of the CRF is large enough to allow the helium to dissipate. As with the SSPF, caution should be taken by personnel going into the upper levels of the CRF. Since helium rises, the risk of an oxygen deficient atmosphere is greater for personnel who work in the upper levels of the building.

During operations at the pad, GSE will be installed and connected to AMS-02. Emergency vents will not be required. Vent paths available at the pad will be used to plumb exhaust gases from the vacuum pump outside the work areas, primarily to limit the possible oil vapor that the pumps generate. Furthermore, vent pumps and CGSE will be in place to pump the cryo-system pressure down to keep the superfluid He down to 1.2K, thus eliminating the need for emergency venting.

During its time in the payload bay at the pad, venting by the AMS-02 will not present a hazard to the shuttle. Refer to the flight safety data package for more details.

The hazards and controls for the loss of breathable atmosphere have been addressed in GHR-AMS-02-007. More detailed information of the venting analysis is found in the ESCG memo “Helium Venting Analysis” prepared for review by the KSC GSRP.

7.8 Ionizing Radiation

The TRD calibration tubes that originally contained ⁵⁵Fe iron citrate—a source of the ionizing radiation, have been removed from the Payload. The hazard report (GHR-AMS-02-008) discussing the hazards and controls for ionizing radiation has been withdrawn. .

7.9 RF Radiation

The GPS ground testing equipment has been reviewed by the KSC Health Physics office to find out if it poses an RF radiation hazard. The conclusion is that the GSE is exempt from the requirements of KNPR 1860.2 and 45-201 as per IEEE C-95.1 (2005) and therefore does not present a hazard to ground personnel (E-mail from Ennis Shelton to Tom Tinsler dated April 8, 2008).

7.10 Structures

Structural failure was divided up into static and dynamic operations. Static structural hazards are concerned with the structural stand hardware (PSS). The causes for structural failure while static include inadequate structural design and improper assembly of the PSS vertical corner supports, as well as structural failure of the CGSE cryogenic/vent line support stands. These will be controlled by ensuring proper procedures are followed during assembly and that support hardware meets the requirements of KHB 1700.7C. The PSS is designed to support the load of both personnel and small hand tools.

The hazards and controls for structural failure during static operations have been addressed in GHR-AMS-02-010.

The dynamic structural hazards are concerned with the lifting equipment. The causes for structural failure include inadequate structural design, structural deterioration, the improper attachment of swivel hoist rings, overloading of the lifting equipment, improper assembly, and personnel error.

Inadequate structural design is controlled through designing the lifting equipment with safety factors for crane, forklift, and dolly operations. Structural aging will be controlled through daily inspections of the lifting equipment and annual structural inspections. Swivel hoist rings will have specific torque values and will be visually inspected before use. Eyebolts that can be removed will have a positive means to ensure complete engagement. Permanent lifting points on GSE will have an ultimate factor of safety of 5. To prevent overload, lifting equipment will have pertinent load information located on it. The lifting equipment will only lift AMS-02 flight hardware and GSE. Procedures will preclude the improper assembly of the lifting equipment. Personnel error will be controlled by using only KSC certified personnel to perform heavy lifting operations.

The hazards and controls for structural failure during static operations have been addressed in GHR-AMS-02-009.

7.11 Electrical Systems

There are a variety of electrical systems that could be hazardous to ground personnel. Typical causes of electric shock include over voltage/current, personnel coming into contact with high voltage sources, the mis-mating of power connectors, the possibility of water leakage, ungrounded components of AMS-02 or its GSE, and shorting an energized circuit during connector mating/de-mating.

Circuit protection devices are designed to National Electric Code NEC or equivalent standards, which will control over-voltage/current hazards. To preclude contact with high voltage/current sources, socket connectors will be used on the power side of GSE. High voltage/current sources will be labeled for those circuits accessible to personnel, and lock-out/tag-out procedures will be implemented during maintenance operations. Mis-mating of powered connectors will be precluded through use of connector keying. Water leakage will be precluded by proper assembly of the vacuum pump cooling system and ensuring hoses and connectors can handle the water pressure. Proper grounding and bonding between AMS-02 hardware and KSC facilities, including power cords using non-current carrying ground conductors, will prevent conductive external parts from shocking personnel. Mating de-energized electrical circuits will prevent shorting payload or GSE electrical circuits.

The hazards and controls for electrical shock have been addressed in GHR-AMS-02-011.

7.12 Acoustics

Excessive noise levels (above 80 dB constant, 140 dB impulse) could cause hearing damage or loss to personnel. Hearing protection will be required for personnel to protect them from constant high level noise, if required. The vacuum pumps will be enclosed in sound-absorbing housing.

Monitoring AMS-02 systems for pressure and temperature increases will warn personnel of impending burst disks.

The hazards and controls for hearing loss have been addressed in GHR-AMS-02-012.

7.13 Magnetic Fields

The AMS-02 utilizes a superconducting magnet and can create strong magnetic fields when charged. This could result in equipment malfunction and excessive loads. To control this hazard, the

design of the coils of the magnet limits the strength of the fields outside of the core. The magnet's avionics box limits the maximum current that the magnet can receive, thus limiting magnetic field strength. Procedural controls, such as using non-magnetic tools and placement of warning signs, will be used to keep vulnerable equipment outside of magnetic field range.

The hazards and controls for excessive magnetic fields have been addressed in GHR-AMS-02-013.

7.14 Sharp Edges

Sharp edges on either GSE or flight hardware could cause personnel injury or equipment damage. GSE will be designed to meet the requirements of MIL-STD-1472 and NASA-STD-3000. For items such as lock wire, procedures will be in place to ensure that sharp edges are controlled. For flight hardware, it will be designed to NSTS 07700, Vol. XIV, Appendix 7 (specifically, the star tracker baffles). For sharp edges that cannot be controlled, keep-out zones will be established to prevent personnel contact.

The hazards and controls for sharp edges have been addressed in GHR-AMS-02-014.

7.15 Lasers

Lasers are located in the interior of the AMS-02. Exposure to lasers could cause personnel injury. Control of this hazard includes the inherent design of AMS-02 in which the lasers are inside closed boxes and are conducted to the interior of the tracker via shielded optic cables. The connectors and cables are under thermal blankets, adding another layer of optical protection. In addition there are no nominal or contingency operations requiring access to the lasers or the laser beam path.

The hazards and controls for lasers have been addressed in GHR-AMS-02-016.

7.16 Biomedical Subsystems

There are no biomedical subsystems on AMS-02 flight or ground hardware.

7.17 Ordnance

There is no ordnance on AMS-02 flight or ground hardware.

7.18 Mechanical and/or Electromechanical Devices

There are no mechanical or electromechanical devices on the AMS-02 flight or ground hardware.

7.19 Propellants

There are no propellants on AMS-02 flight or ground hardware.

7.20 Oxygen

There will be no stored liquid or gaseous oxygen on AMS-02 flight or ground hardware.

7.21 Batteries

All batteries associated with AMS-02 and its GSE are COTS. The exceptions are two UPS boxes that contain an eight cell lithium ion battery per box. They are located on the USS in battery boxes. They are used to assist in shutting down AMS-02 in case of power or communication loss with the ISS. During the operation of AMS-02 at KSC, it will be trickle charged, which is standard operating procedure. There are no charging operations conducted by ground personnel.

For more information regarding the ECAD UPS batteries, please refer to flight hazard report AMS-02-F13, "Battery Failure" and the AMS-02 EP-5 "Battery Design Evaluation Form", tracking number EP-06-19, found in Appendix E of the flight safety data package.

7.22 Safety Related Failures and Mishaps

There have been no safety related failures or mishaps with the AMS-02 GSE to date. A list of flight-related failures and mishaps will be forwarded to the GSRP under separate cover.